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ABSTRACT

Presented is a study and recommendations regarding the role of the Environmental Protection Agency (EPA) in developing skilled water quality control personnel. The American Academy of Environmental Engineers, which conducted this analysis, concludes that the federal role should be a major one. Furthermore, the present EPA policy of leaving labor force development primarily to marketplace influences is inappropriate and fails to respond to a national need. The EPA should take a leadership position in assuring and financially supporting an appropriately trained environmental workforce of adequate size. The documentation offered includes college enrollment figures, results of a survey of a panel of individuals with knowledge of labor force problems, and descriptions of existing training systems. (Author/WB)

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An Analysis of the Role of the U.S. Environmental Protection Agency in the Development of Manpower for Water Pollution Control

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For

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Municipal Operators and Training Division
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Washington, D.C. 20460

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EXECUTIVE SUMMARY

The American Academy of Environmental Engineers has concluded that the present EPA policy of leaving manpower development primarily to marketplace forces is inappropriate and fails to respond to a growing national need. EPA should provide leadership and financial support in assuring an adequate and appropriately trained environmental workforce.

There is presently a lack of trained manpower for many important environmentally related tasks. Strain and need on such manpower supply is evident in both new and established programs.

Although the federal government has an important stake in the production of an adequate supply of competent environmental manpower, and a legislatively mandated role in this area as well, EPA severely cut its support of professional training during the 1970s. EPA believes that "the free market is now ready to take over" the training of professional manpower. For a number of reasons, however, the marketplace cannot effectively handle environmental manpower problems. Such forces are slow and unresponsive. They are especially so in the environmental field, where the high proportion of governmental and educational workers distorts market conditions. Marketplace conditions actually are damaging to at least one aspect of the field--they discourage B.S. level engineers from entering graduate school.

The recent experience of graduate training programs for environmental specialists attests to the inability of the marketplace to supply adequate environmental manpower. The number of Master's level graduates being produced at present is little more than half the annual production of the early 1970s, despite burgeoning environmental problems.

While it was never intended that EPA be the sole support of environmental education, it is clearly the responsibility of the agency to identify specifically the specialized manpower requirements for the implementation of its legislative mandates and to provide educational support, particularly financial, necessary to assure that these human resources are available. EPA should assume leadership in providing the supply of required, trained manpower for environmentally related tasks. This recommendation is in harmony with the findings of past environmental manpower studies, including those of the 1977 National Academy of Sciences study.

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An Analysis of the Role of the U.S. Environmental Protection Agency in the Development of Manpower for Water Pollution Control

SUMMARY

The American Academy of Environmental Engineers has analyzed the question of what should be EPA's proper role in the development of manpower skilled in water quality control. The Academy has concluded that the federal role should be a major one, and that the present EPA policy of leaving manpower development primarily to marketplace forces is inappropriate and fails to respond to a growing national need. Its reasons for adopting this policy are unpersuasive. EPA should take the leadership role in assuring an adequate and appropriately trained environmental workforce. Financial support is an important part of this leadership responsibility.

The environmental protection field is explosive in terms of the range and complexity of the proliferating problems it must address. There is nothing esoteric about these problems -- they are immediate, pressing, and ubiquitous -- from chemical contaminants such as halogenated hydrocarbons in water supplies, to acid rain, which complicates the nation's energy planning and its international relationship with Canada.

Environmental problems evolve constantly, but their evolution often appears to be discontinuous -- they arise unpredictably. Who, three years ago, could have effectively anticipated such environmental threats as Love Canal and Kentucky's Valley of Drums? Though undoubtedly there were some individuals who sensed such threats, nothing was done to forestall their development into crises situations. Like many other environmental problems -- including the kepone contamination of the James River, the PCB contamination of the Hudson River, and the possible fluorocarbon threat to the ozone layer -- the hazardous waste crisis sprang full-grown into the public consciousness, to the accompaniment of public fear and scientific uncertainty.

Such environmental problems hit hard for a number of reasons, a major one being that we lack skilled manpower to effectively anticipate them and to expand our often scanty knowledge of how to deal with them. A highly skilled workforce, adequate in numbers and prepared to communicate effectively with workers in the allied sciences, must be the heart of the environmental protection effort. A complication in this respect is reluctance of private consultants to guarantee the design of remedial works, since the risk of failure could be high. EPA should seek to employ the best skills available in such cases, while relieving the consultant of financial and legal responsibility he would normally assume.

There is a lack of skilled manpower for many important tasks. This is evident in our slowness to assess the relative importance--whether great or small--of new problems and to devise responses that are appropriate. A first logical step would be to define quantitatively what constitutes an adequate manpower base for the many specific tasks essential to comprehensive water quality management. These range from routine technician-level functions at wastewater treatment plants to the policy setting and decision making functions of federal and state planners. Our national manpower requirements are yet to be projected in terms of specific numbers for each major task category and in production rates of trained workers to meet our skilled manpower needs.

Estimates of need are feasible for at least certain categories of personnel, for example, wastewater treatment plant operators and technicians. Such estimates may be extended to categories of manpower required by state water pollution control and water supply agencies. These estimates should be made when possible, and they may best be made by the EPA.

We recognize the substantial uncertainty which now exists in projections of many other worker categories. This is particularly true for specialized manpower required when unexpected problems are recognized, or new unanticipated responsibilities are placed on federal and state regulatory agencies. This

uncertainty is unfortunate; it is a major justification for the development of special training programs that will prepare such workers to undertake new tasks, or to move in new directions.

Strain on manpower supply is evident in both new and established federal programs. The new hazardous material clean-up program that must be developed if the proposed "super fund" legislation is enacted will make heavy demands on appropriately trained personnel. EPA estimates that approximately 3000 man-years of effort involving a wide variety of skills will be required by this program during the foreseeable future. But the well-established wastewater treatment facility construction grants program is also suffering from a shortage of skilled manpower. EPA has established that more than half of the facilities constructed under the program fail to perform up to design specifications. The nonperformance is attributed partly to faulty design (probably due to insufficient trained personnel in the design firms) but mostly to improper operations and maintenance. These are fundamentally manpower education problems.

The problem of manpower goes beyond the need for personnel adequately trained to operate and maintain treatment facilities, critical as this need is. The problem extends to preparation of personnel adequate in number and training to monitor our drinking water and waterways, devise appropriate treatment schemes, and do the kind of planning that is necessary to relate these efforts to specific local, regional, and national needs. It includes, too, the very special preparation required by those on whom the public depends for solutions to the emergencies of today and the new problems of the future. AAEE, whose function is to assure a high level of competence among those who make their careers in pollution control, is concerned over the inadequacy of current EPA support for development of this critical manpower.

The Environmental Protection Agency should support environmental training. This is a suitable and appropriate role for the federal government to play, and one for which ample precedent exists. In its 1975 report, the Federal Interagency Commission on Education (FICE) noted that federal involvement in areas such as research and development is so dominant that government decisions have a far-reaching impact on both supply and demand for knowledge and manpower. The

question is not "whether or not", said FICE, but rather "how much" and "in what areas" support is necessary. Environmental training is a prime candidate for support. The federal government has an important stake in the production of an adequate supply of skilled environmental manpower; it also has a legislatively mandated role in this area.

Under pressure from the Office of Management and Budget, EPA severely cut back its support of training of professional manpower during the middle and late 1970's. The agency has reduced its staff for all kinds of training by approximately half during the last several years. In 1976, and in every year since then, it has attempted to eliminate completely its support of graduate level training. Only intervention by Congress has kept this program alive.

EPA bases its policy of eliminating support for graduate pollution control training on the belief that "the free market is now ready to take over", that is, that market forces will tend to assure an adequate supply of properly trained environmental manpower to meet the country's needs. This view is incorrect. For a number of reasons, the marketplace cannot effectively handle environmental manpower development.

Environmental manpower supply is not just a numbers problem; the quality of the workforce, and its composition, are fully as important as its size. Market forces alone cannot address the quality side of the problem. Marketplace forces do tend to provide that, if a given number of positions are open, then approximately that number of positions will be filled, but such forces cannot assure that they will be filled either appropriately or effectively. In its 1977 study on pollution control manpower, the National Academy of Sciences observed that the supply of environmental engineers has been significantly augmented by crossovers from other fields. Such intermixing may have some benefits, but there is little reason to believe that its net effect will be beneficial in a field as technically demanding as pollution control. Crossovers rarely have had the training necessary to be true environmental engineers and are, therefore, often poorly equipped to interpret complex instructions or assess decision impacts.

The suddenness with which new environmental problems often arise points up another danger of depending on the marketplace to produce the needed force of engineers, scientists, and technicians. Market forces operate too slowly and too unresponsively to supply personnel capable of dealing effectively with rapidly evolving problems. Environmental protection, more than many fields, is an area in which "an ounce of prevention is worth a pound of cure". Market forces cannot effectively supply manpower to serve this "preventative" function. The results are too few qualified persons assigned to highly important tasks, a delayed response, and a poorly protected public. In its 1975 report on federal support of graduate education, FICE presented as one of the basic principles for such support this concept: that in situations where market response would be slow and the social cost of such a slow adjustment is high, then federal stimulation of a response to changing manpower and knowledge needs would be justifiable. Development of an environmental workforce for protection of public health and welfare presents such a situation.

A further weakness in the marketplace argument is related to the fact that less than half of those working in the environmental field are employed by private enterprise. In order for the free market concept to be applicable, salary levels and numbers of positions must be readily changeable to respond to changing market conditions. However, about 43% of the environmental workforce is employed by government and almost another 10% by educational institutions, where this kind of rapid response simply does not occur. The environmental marketplace is thus a distorted one, and cannot be expected to function even as effectively as a true free market.

It is also relevant in this connection to point out that the 1975 FICE report indicated that in cases where federal employment involves a high percentage of personnel in a particular area, it is cheaper for the government to finance their training at universities than to train them itself or to wait for market forces to supply them.

Far from assuring an adequate supply of appropriately trained environmental manpower, marketplace conditions are actually damaging to at least one aspect of the field -- they discourage B.S.-level engineers with exceptional promise

for advanced study from entering graduate school for specialized environmental training. According to the Scientific Manpower Commission, the average starting salary for an engineer with a B.S.C.E. in 1978-79 was $1,402 per month. The starting salaries of graduates from M.S.C.E. programs (often the degree earned by environmental engineering specialists) is not substantially higher than this, only $1,595 per month. Thus, there is not a major economic incentive at present for an engineer to go beyond the bachelor degree level.

Without financial support, such as EPA formerly supplied, graduate school becomes even less inviting. All technical fields need a percentage of highly trained specialists to provide direction and long-term research capability, including the preparation of highly skilled research workers. This need is particularly acute in the technically challenging, constantly changing environmental field. Market conditions that discourage graduate training may well prove damaging in the long term.

The drawbacks inherent in relying on the marketplace to supply the necessary number and mix of environmental personnel are exacerbated by the fact that, while environmental problems are widely recognized, the fields of environmental science, engineering, and technology are not generally familiar to the public. The environmental fields suffer in competition with the better-known technical and scientific specialties. Graduate stipends and training support are therefore especially useful as recruiting tools for environmental education programs.

Thus, there are major reasons why it is not reasonable to expect market forces to effectively replace federal support of environmental training. The contention that the marketplace alone cannot do the job is, in fact, borne out by the recent shrinking of graduate training programs for environmental specialists.

Environmental problems have proliferated during the years since EPA decided to phase out its graduate training support program. Nevertheless, the output of graduates from the schools has been markedly reduced during this period. From

a high of about 2400 in 1972, the number of master's level graduates with environmental engineering specialities plummeted to 1000 per year by the middle of the decade. The number of new M.S.-level students in wastewater engineering fell from 1200 in 1972 to only 400 in 1976, a distressing 68% decrease. There has since been some tentative and partial recovery and the number of graduates in 1978 (the most recent year for which data are available) reached about 1400 -- still little more than half the level of the early 1970's. Demonstrably, the private sector has not taken over training costs, and there is little reason to expect that it will do so in the future. Many schools are finding that, because of the relatively small size of environmental departments and the very specialized nature of the training that must be provided, they simply cannot afford to offer strong, balanced environmental training programs without federal support.

A weakened training base for professional manpower in pollution control impairs our ability to protect the nation's natural resources and the public welfare. This function is inherently part of the role of government. Private enterprise regards environment primarily as a raw material and commonly finds environmental protection measures to be a restraint on normal business. The push for environmental protection has been public, not private; and the driving force for reform has been federal legislation. This dichotomy between the interests of government and those of private enterprise is a fundamental reason why responsibility for environmental protection functions cannot be shifted from the public to the private sector, and why the government has a special responsibility to assure an adequate supply of properly trained environmental manpower.

Where there is a shortage of adequately trained environmental personnel, the pinch is felt most strongly in the public sector, particularly at the state and local levels, because careers at these levels of public service are generally less rewarding financially than those in the private sector, and therefore less attractive. Government, therefore, has a very direct stake in the manpower question.

Furthermore, it is the public agencies that are in the front line when new environmental threats arise, and that require flexible, quickly adjustable programs to provide skilled professional workers in times of stress. It is also the governmental agencies that must decide on the technical feasibility of pollution control methods proposed by potential polluters. Such agency decisions often call for large expenditures which may affect the economy of the areas involved.

EPA not only makes important decisions affecting the expenditure of private funds on pollution control, it is also a big spender in its own right. More than $20 billion has been appropriated for the agency's construction grants program. Skilled, well-trained personnel are the key to reducing capital costs for treatment facilities, through design innovations, and to controlling soaring operation and maintenance costs, which are a source of growing concern. It is fully reasonable for EPA to spend some public funds on training in the interest of restraining overall public expenditures, and in protecting the investments of the taxpayers.

An additional federal priority is affected by the environmental manpower training program. Many studies have shown that the impact of environmental degradation is greatest on people from minority and low-income groups. Career opportunities in environmental health can help fill the needs of such people to work in a field relevant to public health. Since students from such groups tend to have less of the financial resources necessary to become qualified in this field, their only hope is through the mechanism of federally supported training programs. Without such programs, members of minority and disadvantaged groups have essentially no opportunity to become qualified for work on environmental health related projects.

If the federal government elects to reduce or eliminate environmental manpower training, the states are unlikely to take up the slack. Funding for training programs is usually considered to be "soft money" in state budgets, and is

one of the first items to be cut. Furthermore, trained environmental personnel move freely from local and state jobs to federal agencies or other states so there is no assurance that a state would benefit from money spent on training personnel. However, trained environmental personnel are a national resource and help to achieve the goals of federal legislation wherever they work, be it in a federal or state regulatory agency, a local treatment system, a facilities design office, or elsewhere in an environmental job.

Federal support of training is an EPA legislative mandate. Congress provided authority for a wide variety of training activities in the environmental statutes it has enacted. The Clean Water Act contains provisions for professional graduate training, research fellowships, direct training, technician training, curriculum development, operator and instructor training, and workforce forecasting. Similarly, the Clean Air Act includes provisions for professional graduate training, graduate fellowships, consortia support, special programs, short-term technical training, and work force forecasting. Federal solid waste legislation also authorizes expenditures for training and education.

Clearly, federal support of training activities is part of the plan envisioned by Congress. While it was never intended that EPA be the sole support of environmental education, it is clearly the responsibility of the agency to identify specifically the specialized manpower requirements for the implementation of its legislative mandates, and to provide the educational support, particularly financial, necessary to assure that these human resources are available.

A federal share of responsibility applies to a wide variety of personnel needed in the water quality/environmental field, including:

a. technicians who operate the treatment facilities, who need a high school education plus a certain level of technical training;
b. professional engineers who analyze environmental problems and develop solutions and who supervise, and regulate pollution control facilities, who need a minimum of a bachelor of science degree plus graduate education to the masters degree level; and

c. highly educated scientists and engineers who normally need a doctorate to develop basic knowledge, plan and direct the graduate educational programs, and do supporting research.

The federal interest applies also to a range of educational programs needed to train this variety of personnel, including:

a. undergraduate and graduate educational programs to provide a relatively large number of well educated personnel on a year-to-year basis through associate, bachelor and Master's degree programs
b. graduate level university programs to provide a relatively smaller number of doctoral level people to plan and direct the academic and research programs;
c. continuing education (short course) programs to provide updating for large numbers of environmental personnel at all levels already working in the field; such courses should be widely available; and
d. special university-centered crises training programs to address environmental emergencies.

It must be recognized that traditional education and training methods alone cannot supply the needed skills and that continuing education programs are of key importance. All levels of training should be oriented to current and future problems and ways of dealing with them, rather than to the perpetuation of past practice. As part of this effort, the methods of providing continuing education must also be evaluated and improved. The development of novel, highly effective means of knowledge transfer for all practitioners, at all levels and in all specialties, merits high priority. EPA's recently initiated programs toward this end justify optimism.

There is also a need for a further very specialized kind of training program, which might be called crises training. These programs, probably university-centered, should have the ability to marshal money, people, and resources to

rapidly develop the methodologies for dealing with true environmental crisis situations as they arise. The Love Canal situation provides an example in which such a flexible and high-powered program could be helpful. Successful handling of incidents such as the one at Love Canal requires the development of knowledge and skills in a spectrum of specialties, including transport of hazardous materials within the ground, diffusion of these materials into water supplies, fate of the substances in situ, diffusion of volatiles, specific measuring methodologies, and specialized clean-up techniques.

Crisis training centers could rapidly mobilize the available basic knowledge that must be brought to bear to resolve environmental crises. Such programs could meet the immediate demand for trained personnel, and also concurrently develop curricula relevant to the particular problem area, which could then be incorporated into training materials for all levels of environmental education, all the way down to the two-year technologist level. However, no university could or is likely to undertake such activities without financial support.

The question of skilled manpower shortage cannot be answered simply in terms of how many positions with the word "environmental" tacked onto their titles are filled. The critical question is: Are the right number of people with the right kind of training available? This is not an easy question to answer. Since environmental staffing is more than a numbers problem, the supply may appear to be adequate when, in fact, it is not.

Environmental manpower surveys have repeatedly predicted shortages. The most extensive survey to date, the National Academy of Sciences report on Manpower for Environmental Pollution Control (1977) concluded that there will be no overall shortage, but predicted spot shortages in specialized areas. It recommended (page 383):

> "To assure that there will be available professional, technical and operational personnel needed....it is recommended that the Federal government encourage and financially support substantially increased academic and other personnel training programs without further delay."

In response to a congressional request, EPA prepared in May 1979 a report on what the agency felt its proper role should be in assuring adequate environmental manpower through graduate training support. The EPA report relegates direct support of graduate training to the lowest priority of any training activity considered by the agency. The reasons given for this low ranking are not persuasive.

The key factors affecting EPA's position on graduate training support are, according to the report: (1) concern over causing an "overkill" effect similar to the post-Sputnik push for scientists and engineers in the 1960's; (2) a policy of encouraging state self-sufficiency in environmental programs; and (3) the lack of state and regional data on which critical shortages exist. None of these "key factors" stands up very well under scrutiny.

The agency's concern regarding overkill would be reasonable if there were any observable signs that an oversupply of environmental specialists was developing or had ever existed. There has been no such sign. On the contrary, all major environmental manpower surveys to date, including the voluminous NAS report, have predicted at least spot shortages of personnel. A 1977 report prepared for EPA and NAS projected that an additional 8000 engineers would be required by just the public sector by 1985 in the wastewater area alone. The EPA report itself claims no more than that "at present, there is little objective information to show whether or not the supply of graduates is adequate in comparison with demand." How then, did fear of creating a surplus come to be a key factor in discouraging the funding of graduate training? There is no evidence to support such concern.

EPA's policy of encouraging state self-sufficiency in environmental programs is sound and very much in keeping with the will of Congress, but it has little to do with graduate training support. States can approach manpower sufficiency through state-supported training in such areas as assumption of permit program and construction grant program responsibilities. But states do not have the

history of broad training support appropriate to the federal government, and they are unlikely to develop such traditions. EPA acknowledges in its 1979 report that its effort to encourage workforce planning at the state level and to encourage the use of in-state university systems to meet professional training needs "has met with little success."

The final "key factor" cited in the report -- lack of data on where shortages exist -- is difficult to understand. Lack of data is a poor basis for a policy decision and in itself reflects insufficient EPA attention to an important responsibility.

The monies necessary to permit EPA to assure that adequate, properly trained manpower is available to realize the nation's environmental goals are not of a magnitude to have a significant impact on the agency's overall budget. It may rather be that, because they are so small in comparison with many other budgetary items, they are viewed as incapable of accomplishing anything of significance. Actually, just the opposite is true. The few million needed for manpower training represent a sound investment that will produce an excellent return to the taxpayer. It would have a major impact on the worth of the billions of dollars spent on facilities construction and other efforts to control pollution now and in the future. To neglect training in the name of savings is to risk much to save little.

The Environmental Protection Agency should re-think its position on support of manpower training. In the words of the National Academy of Sciences report, "It is not realistic to assume that training of needed environmental manpower will occur without incentive and financial support instigated by the federal government....EPA especially, should assume leadership for the responsibility in providing the supply of required manpower." The American Academy of Environmental Engineers endorses this recommendation and offers to EPA its assistance in the complex task of developing realistic assumptions and appropriate strategies for meeting this responsibility.

It is recommended that a monitoring function be performed under the auspices of the Environmental Protection Agency. This does not necessarily need to be a

unit within government but could be operated under EPA funding in the setting of a university or commercial organization. This "human resources monitoring unit" would have two main functions: early warning and reporting of acute problems. The early warning activity should be closely tied to the monitoring apparatus already in place. That apparatus is predominantly in the hands of other government agencies; namely, the Bureau of Labor Statistics, the Office of Education, and the National Science Foundation.

It is recommended that EPA enter into negotiations with the Bureau of Labor Statistics and the U.S. Office of Education to the end that the routine processes of data collection conducted by these agencies be marginally adjusted to optimize the applicability of the data to the particulars of pollution control.

AAEE is prepared to form a standing committee to work with the Agency in identifying manpower problems and assessing needs, primarily in those areas dealing with environmental crises. The Academy also offers to EPA its assistance in developing and managing programs for manpower training that are responsive primarily to crisis situations.

Chapter 1
The Role of the American Academy of Environmental Engineers

The formulation of public policy is an increasingly complicated process. It is particularly complicated in a modern democratic society because the parties-at-interest in any given policy deliberation are increasingly diverse (in some case, polarized) and the linkages between legitimate interest in a given issue and substantive expertise are often increasingly tenuous.

In the United States a system of deliberation has evolved that makes explicit use of non-governmental organizations as sources of knowledge in support of the deliberative process. Organizations such as the National Academy of Sciences are prominent contributors to the process.

When public policy deliberations are directed toward questions of human resource development in a given occupational or professional domain, it has become almost a standard practice to call upon one or more of the national organizations that represent that professional community. The community of peers that is so represented cannot be the only source of information in such policy deliberations because it is recognized that the professional group, as a form of guild, has values and interests that are not universal. However, the professional group does have an obligation to assert its own interests in such matters and to do so in such a way as to identify and emphasize those areas in which the interests of the professional community and the welfare of the citizenry converge.

Public policy in the matter of human resource development in the field of environmental pollution control is now an open matter for debate. We are drifting toward a potentially severe problem in this area. In the chapters that follow, the story of the ups and downs in this area will be documented.

The EPA construction grants program, through which the federal government subsidizes construction of local water pollution control facilities emphasizes the growing problem regarding availability of skilled environmental personnel. There is little question that the expansion of facilities will continue to take place at a relatively rapid rate. However, while the government is providing money to construct these facilities, it is apparently giving little thought to the personnel required to do the basic study, design and operation that will make the facilities effective.

Our ability to staff these facilities with adequately trained personnel and to staff the complex infra-structure of organizations that support these operations is uncertain at best.

The Academy has been requested to analyze this problem and to respond by providing its views for the deliberative process. The overall question in the forefront of that deliberative process is: What should the federal role be in the development of human resources for water pollution control?

Before turning to the substance of that question, however, it is necessary to describe fully the historical development of the Academy and its credentials for taking on an advisory posture in this area.

The American Academy of Environmental Engineers has a special interest in the education and training of engineers and technologists who will subsequently enter professional practice in the areas of environmental engineering and environmental control.

The Academy was founded in 1955 through a joint committee of five founder societies, and was incorporated under the name of the American Sanitary Engineering Intersociety Board (ASEIB). This incorporation provided for certification of sanitary engineers as Diplomate of the American Academy of Sanitary Engineers (AASE). The ASEIB was renamed the Environmental Engineering Intersociety Board in 1966, and the name of the roster was changed to the

American Academy of Environmental Engineers. In 1973 the Board and Academy were merged into one organization named the American Academy of Environmental Engineers (AAEE). The five sponsoring bodies already held common and overlapping interests in the environmental engineering field through the activities and involvement of a significant number of their respective members. The joint committee was now seeking a way to identify, recognize and coordinate activities of environmental engineers from diverse backgrounds, and in diverse activities, to better serve the public through improving the practice of environmental engineering, elevating qualification standards for environmental engineers, and providing a more definite recognition of environmental engineering as a profession. The five founder societies were the American Society of Civil Engineers (ASCE) , the American Society for Engineering Education (ASEE), the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Pollution Control Federation (WPCF). Five other organizations have since become sponsoring members of the Academy. Listed in order of their joining they are: The American Institute of Chemical Engineers (AIChE), the Air Pollution Control Association (APCA), the American Public Works Association (APWA), the National Society of Professional Engineers (NSPE), and the Association of Environmental Engineering Professors (AEEP). Representatives of each of these sponsoring societies serve on the Board of Trustees, which is the policy-making and management arm of the Academy. The Academy encourages close working relations with these and other professional and technical organizations which have goals and objectives that are compatible with its own. The Academy has evolved during a period of growing recognition that environmental engineering embodies a collection of knowledge transcending the major objectives of the founder societies, and cutting across the domains of all these societies. The interdisciplinary nature of engineering called for a group such as the Academy to assume a leadership role in defining the scope of education activities and programs, as part of its more general objectives of public service, identification of qualified engineers, and upgrading of the profession.

Today the Academy has a membership of some 2000 registered professional engineers who are active leaders in the many facets of environmental engineering included in private practice, industry, government, and education. Certification as a member of the Academy is granted upon examination to registered professional engineers active in general environmental engineering, water and wastewater engineering, air pollution control, solid waste management, industrial hygiene, and radiation protection. Applicants must have eight years of practical experience, four of which have included active environmental engineering participation in "responsible design, management, research, administration or teaching." Certification by invitation may be granted to engineers selected by the Board on the basis of their eminence and outstanding contribution to the profession.

The Academy was founded "for the principal purpose of serving the public by improving the practice, elevating the standards and advancing the recognition of environmental engineering through a program of certification of qualified engineers." Espoused standards and goals include the "optimum use of the air, land and water resources and the management of urban development leading to improvement in the quality of life." The primary objective of the Academy is to work toward the advancement of all aspects of environmental engineering. To this end,the bylaws of the Academy provide for an Education Committee with representation by educators and practitioners from the several specialty areas. As further evidence of its increasing interest in engineering education, the Academy, in 1978, became a Member Body of the Engineers' Council for Professional Development (ECDP), now the Accreditation Board for Engineering and Technology (ABET) the recognized accreditation authority for engineering education programs, and has designated representation to the Council and committees of this organization.

The majority of members of the Academy are from private practice and government rather than from academia. Thus in large measure they are the employers of the products of the educational system. For this reason they have a deep concern

both for the quality of education and for the number of students being trained at the various academic levels of entry into the profession. Involvement in the quality standards for educating baccalaureate and advanced-level students recently culminated in the preparation of a "Guide for Environmental Engineering Visitors on ECPD Accreditation Teams". This guide was prepared by a joint ad-hoc committee with representation from the Academy, ASCE and AEEP.

In 1960 the ASEIB sponsored a conference at Harvard University on graduate education of sanitary engineers. The conference was primarily concerned with the structure and course content of graduate programs, and the need for accreditation of such programs. The first directory of graduate sanitary engineering programs was as a result of this conference. In 1967 the EEIB, jointly with the American Association of Professors in Sanitary Engineering (AAPSE), the precursor to AEEP, sponsored a Second National Conference at Northwestern University which again dealt mainly with the curricula of graduate programs and the question of program accreditation. This conference received support both from the U.S. Public Health Service and the National Science Foundation. In 1973 the Academy, again with AEEP, sponsored the Third National Conference on Environmental Engineering Education held at Drexel University. This conference, made possible by a grant from EPA, addressed a broad range of educational problems at different academic levels in the various areas of specialization. The report of this conference also presented a compilation of manpower needs surveys in the specialty areas of air pollution control, solid waste management, radiological hazard control, pesticide hazard control and water supply and pollution control. The Academy recently co-sponsored, with AEEP a fourth such conference, held in June 1980 in Toronto, Ontario.

The increasing awareness of long-term effects of pollutants in the environment, the stepped-up activity to monitor pollution levels of both the known and newly recognized contaminants, and the need to plan, design and construct more effective pollution control and waste treatment works throughout the nation will require engineers with increased competence and advanced training. In the field of environment control, more emphasis is being placed upon strengthening engineering education not only for those who will become researchers and teachers,

but also for those who will conceive and carry out the plans for pollution abatement. The need for a more fundamental understanding of factors that affect our environment and how to cope with them places an additional burden on those responsible for education and research. Engineers and technologists must acquire both a broader understanding of pollution phenomena and a deeper insight into the mechanics and processes of pollution control.

Much of the activity in manpower training, particularly at the graduate level has been supported by institutional grants from the U.S. Environmental Protection Agency (in prior years by EPA's predecessors, the Federal Water Pollution Control Administration, and the U.S. Public Health Service). This activity reached its peak in 1973, and has since declined drastically as federal funds have been withdrawn. At the same time, the creation of the EPA itself generated an increased activity demand for trained personnel in the field of water supply and wastewater treatment and disposal. The flood of environmental legislation enacted in the 1970's -- including the Federal Water Pollution Control Act, the Safe Drinking Water Act, the Resource Conservation and Recovery Act and others -- also greatly increased the demand for skilled workers during this period of waning federal support for training.

The increased environmental concerns, which reflect immensely important threats to the environment, now pose a serious question regarding the entry of sufficient numbers of skilled personnel into the water field to perform the needed tasks. The Academy has expressed a growing concern regarding the shortage of environmental engineers. For this reason, and with EPA sponsorship, the Academy has undertaken the task of evaluating the nation's future need for skilled manpower. This has involved analyzing previous manpower reports, gathering additional information where available, and calling upon recognized authorities in the field to assess the future manpower needs for the water supply and water pollution control sector of the environment.

Chapter 2
History of Human Resources in the Water Pollution Field

Society's earliest concern for environmental management stemmed from the association between human health and the quality of water. The design and construction of water and sewerage systems became the responsibility of engineers concerned with public works--civil engineers. In time, those civil engineers who specialized in this evolving field became known as sanitary engineers (now environmental engineers). Engineering colleges that provided a civil engineering curriculum added optional undergraduate courses in microbiology, water supply and sewage disposal. A few colleges provided designated degrees in the sanitary engineering option at the undergraduate level. There was no special financial support for undergraduate students in civil engineering, nor for those electing the sanitary engineering option or elective courses.

In the early part of the century, before rural health problems were completely understood, the Rockefeller and Kellogg Foundations became interested in health problems in the United States and this interest led them into concern for the health of persons living in rural areas. This interest was manifested by financial support of local health projects, including environmental activities, and graduate education in public health, including engineers working in public health. The Kellogg Foundation, for example, supported demonstration health departments where engineers could receive field training after graduate study in public health.

U.S. Public Health Service Training Support

The greatest stimulus to the production of trained manpower for work in the environmental area came with the recognition by the U.S. Public Health Service of expansion of research and education in this field as a national need.

The role of the U.S. Public Health Service in the water phase of the environment was first enunciated in the Public Health Service Act of 1914, as follows:

> "The Surgeon General shall....undertake studies and investigations on the diseases of man, including water purification...."

Originating in the Treasury Department, the U.S. Public Health Service at first provided medical care for merchant seamen; but its role expanded to include providing technical assistance to states, conducting research, and regulating interstate problems. With creation of the U.S. Federal Security Agency in the 1930's, the Public Health Service became a cornerstone of the new agency's concern for people's health.

Financial aid was provided to universities and to students to stimulate graduate education in public health, including the specialty of environmental health. Under this program, state health agencies could recruit sanitary engineers and provide post-baccalaureate education (3 months) and field training (1 month) in environmental health before assigning the recruit to a job in a local or state agency. This type of education was termed a "short course."

Persons with several years of experience employed by health agencies were also eligible for one year of support for graduate education in environmental health at a School of Public Health. (The School of Public Health received institutional support directly from the Public Health Service.) This traineeship paid three-fourths of the employee's salary plus tuition and fees. The employee agreed to return to the health agency to work for at least two years after receiving the education.

The leadership for advances in environmental protection in the 1950's and 1960's came from persons receiving graduate training under this program. The Schools of Public Health at Harvard, Michigan, Minnesota, Tulane, North Carolina, California Berkeley and UCLA expanded their environmental programs during this pre-World War II period and most of the state sanitary engineers emerged from this program.

The Post World War II period was also an era of growth and expansion of population, industry, urban areas, and economic expansion. These gains were

not made without costs to environmental quality. Water pollution originating in municipal and industrial discharges was devastating fish and making water increasingly difficult to treat for drinking. Air pollution became a serious threat. Pesticides such as DDT, first seen as the salvation of people subjected to malaria and other insect-borne diseases, were found to cause long-term environmental damage.

The Public Health Service created major programs concerned with these major problem areas. Many of them developed training programs through administrative budgetary arrangements to meet manpower demands.

There were four principal types of funding for research and education. Some of the research conducted in universities provided important opportunities for graduate education. An important aim of research fellowships was to increase the number of people trained to do independent research. Traineeships were available to persons wishing graduate education in areas with definite public health implications. Some training grants-in-aid were made directly to educational institutions to assist in developing graduate study programs in various areas.

When the Public Health Service established the Robert A.Taft Sanitary Engineering Research Center at Cincinnati, it began a variety of in-service education programs.

G.I. Bill Training Support

During the period from about 1945 to 1955, the single most significant factor in producing trained engineers to work in the environmental health areas was the G.I. Bill. Returning veterans could obtain financial stipends and tuition and some other expenses under this program. Many veterans had some contact with sanitary engineering activities associated with the mobilization and training of troops and in protecting the health of soldiers in war areas that led them to take an interest in pursuing sanitary engineering as a civilian career. Others viewed sanitary engineering as an expanding employment opportunity.

Another outgrowth of WW II was the creation of the United Nations and under it the World Health Organization (WHO). WHO had two influences. One was its broad definition that "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity", which greatly expanded concern for environmental factors. The other influence was the expansion and initiation of environmental programs the world over that demanded trained engineers, many trained in U.S. universities.

Other Training Support

Some states, such as New York, Pennsylvania and New Jersey grant leave with pay to promising employees in the environmental field to obtain up to one year of graduate education. These programs also pay tuition. A minimum period of employment is usually required before these benefits become available, and a commitment to return to the agency is also required. Where educational programs are available to commuters, employees may be supported for part-time enrollment in graduate programs.

Some states set up early in-service training programs for operators of water and wastewater treatment facilities. Continuing education has been extended to research centers operated by EPA. Many universities are deeply involved also.

A few cities have comparable programs. Some private industry assists employees in graduate education, usually on a part-time basis.

Recent Federal Training Support

Specific federal legislation has become an important source of funding for environmental education. Water pollution control legislation provided categorical funding in that area beginning in 1948. The Air Pollution Control Act of 1955, was the first to provide financial support in the area of air pollution. Support for training in solid waste was legislated in 1965.

Federal agencies other than the Public Health Service and its successors also provided educational support. Graduate predoctoral fellowships of the National Science Foundation were available to individuals to pursue graduate work in the physical, biological, engineering and related sciences. The Atomic Energy Commission provided financial support in the area of radiological health. The military services support graduate education for their personnel.

The period from the late 1950's to the early 1970's was one of evolutionary and even revolutionary changes in the federal role in environmental management. The 1958 National Conference on Air Pollution and the 1960 National Conference on Water Pollution illuminated accelerating problems in these areas. The ensuing Report of the Committee on Environmental Health Problems, chaired by Paul M. Gross, to the Surgeon General (1962) called for a greater federal role and specifically addressed manpower needs as part of its deliberations as a key factor in coping with environmental problems. That committee concluded:

> "That a national need exists for establishment and maintenance of a vigorous and integrated effort to maintain controls over the human environment compatible with projections of change in both population and the environment itself.
>
> "That the current 'categorical' approaches represented by Public Health Service divisional programs are incapable of providing either (a) the necessary cognizance of combined multiple effects of environmental impacts or (b) the depth of effort required by individual divisional programs.
>
> "That accommodation to the national needs in environmental health will require the establishment of a strong focal center adequately staffed and equipped to prosecute an effective and integrated program within the Public Health Service and to manage and coordinate a strong extramural research, training, and technical support program utilizing the available institutional resources of the nation.
>
> "That an adequate legislative basis for a sufficient national program in environmental health does not exist at present."

The subcommittee on Manpower Resources and Training made the following recommendations:

1. "The divisional training program providing fellowships and traineeships to students and training grants to universities should be strengthened and augmented. In those instances where authority to undertake these programs does exist, such authority should be sought by appropriate legislation.

2. "A substantial program of environmental health institutional grants to support those universities engaged in programs to graduate education should be instituted.

3. "Support for the training grant programs outlined in the foregoing two recommendations should be increased as quickly as possible to a level of $25 million.

4. "There should be established, in the office of the Bureau Chief, a unit responsible for the formulation of overall policy and administration of the several training grants program. This unit is essential to assure an orderly development of the total program.

5. "Other federal agencies engaged in training activities should take cognizance of the manpower demands which will be imposed upon them by the rapidly expanding field of environmental health and should adjust their programs to meet these new burdens."

Congress expressed its concern through a series of legislative actions that progressed from early technical assistance, research and training efforts to federal responsibility for standards and enforcement. In water pollution, the Federal Water Pollution Control Administration was established in 1964. The next year FWPCA was moved from HEW to the Department of the Interior with the passage of the 1965 Water Quality Control Act. When the Environmental Protection Agency was established in 1970, water pollution programs were transferred to the new agency, as were other environmental programs and associated training activities. Ultimately the amendments of 1972 and 1977 set up a comprehensive framework for the federal effort.

Legislation concerning air pollution and solid waste evolved along similar paths, with air legislation in 1967, 1970, 1973, 1974 and 1977, and solid waste legislation in 1965, 1970, 1973, 1975, and 1976. Aspects of all of this legislation authorized financial support of education activities.

The National Environmental Policy Act of 1969, PL91-190 required that assessment of Environmental impacts be made a part of federal project planning. This Act has undoubtedly had a most significant influence on decision making, but it also placed a great demand on qualified manpower to facilitate the required reviews.

The impact of recent Federal programs to support environmental engineering education is apparent from an inspection of the data on production of graduates. Table I shows undergraduate and graduate degrees awarded in sanitary engineering in the United States, 1900-1958.

These data reflect increases stimulated by the early programs of the Public Health Service, particularly in the Post World War II period. Two-thirds of the Master's degrees were awarded in the period 1947 to 1958. Some increase is noted in the late 1930's and early 1940's, but production was curtailed during WW II.

Table II shows data for the period 1950 to 1973. This information was compiled from Registers compiled by AEEP. The 1965 Register represents data from 56 out of 68 schools queried. The 1969 data represents 45 of 68, and 1973 represents data from 69 of 71 schools. The data in Table II include some non-engineers and others, but these figures may offset the schools not reporting.

The data in Table II were gathered in unequal increments, e.g., 1960-1965, 1966-1968. To obtain a rough picture of general trends, the total number of degrees awarded within each time increment was divided by the number of years in that increment to produce the degree/year data in the right-hand column. Figure I represents data gathered by AEEP on graduate students enrolled 1971 to 1978.

Table III shows the Water Pollution training activities supported by EPA involving academic institutions. A dramatic decline in support is shown after 1975 and 1976, although the tightening began after 1972 and 1973. No support is indicated for 1980. (A few schools, particularly Schools of Public Health, continue to receive support under the Health Professions Educational Assistance Act of 1976, administered by HEW, but the use of these funds for environmental engineering education in future years is in jeopardy.)

Withdrawal of financial support of environmental engineering graduates will have a great impact on productivity. Some schools have been able to maintain

Table I: Undergraduate and Graduate Degrees Awarded in Sanitary Engineering in the United States, 1900-1958

Year	Bachelor's[1]	Master's[2]	Doctor's
1900-34	1,265	207	5
1935	86	35	1
1936	88	18	1
1937	75	51	2
1938	82	42	1
1939	103	51	2
1940	116	70	2
1941	98	68	4
1942	93	45	2
1943	165	24	4
1944	65	32	-
1945	40	33	-
1946	28	60	2
1947	112	143	1
1948	160	163	4
1949	247	136	4
1950	287	148	4
1951	247	152	7
1952	216	[3]105(22)	[3]9
1953	216	102(20)	[3]5 (3)
1954	164	120(25)	9
1955	141	130(34)	11 (2)
1956	208	124(31)	9 (1)
1957	[4]145	[4]152(39)	[4]11 (1)
1958	[4]107	[4]121	[4]16
Total	4,554	2,336(460)	[5]116 (13)

1 No distinction is made between nationals and non-nationals awarded the degree.

2 Of the total of 1,478, 1900 to 1951, inclusive, 289 were awarded to nationals of other countries.

3 Figures in parentheses represent nationals of other countries and are included in the larger figure.

4 Estimated

5 Of the total of 46, 1928 to 1951, inclusive, 6 were to nationals of other countries.

Table II: Degrees Awarded in Environmental Engineering

	Number of Degrees Awarded		Degrees/Year	
Year	M.S. or M.E.	Ph.D.	M.S.	Ph.D.
1950-1959	2,189	248	219	25
1960-1965	1,231	185	246	37
1966-1968	739	117	369	58
1968-1969	361	97	361	97
1969-1970	396	90	396	90
1970-1971	571	96	571	96
1971-1972	804	137	804	137
1972-1973	812	101	812	101

These data reflect increasing financing and public interest.

Figure 1.
Graduate Students Enrolled in Environmental Science,
Water and Wastewater Engineering, 1971 – 1978

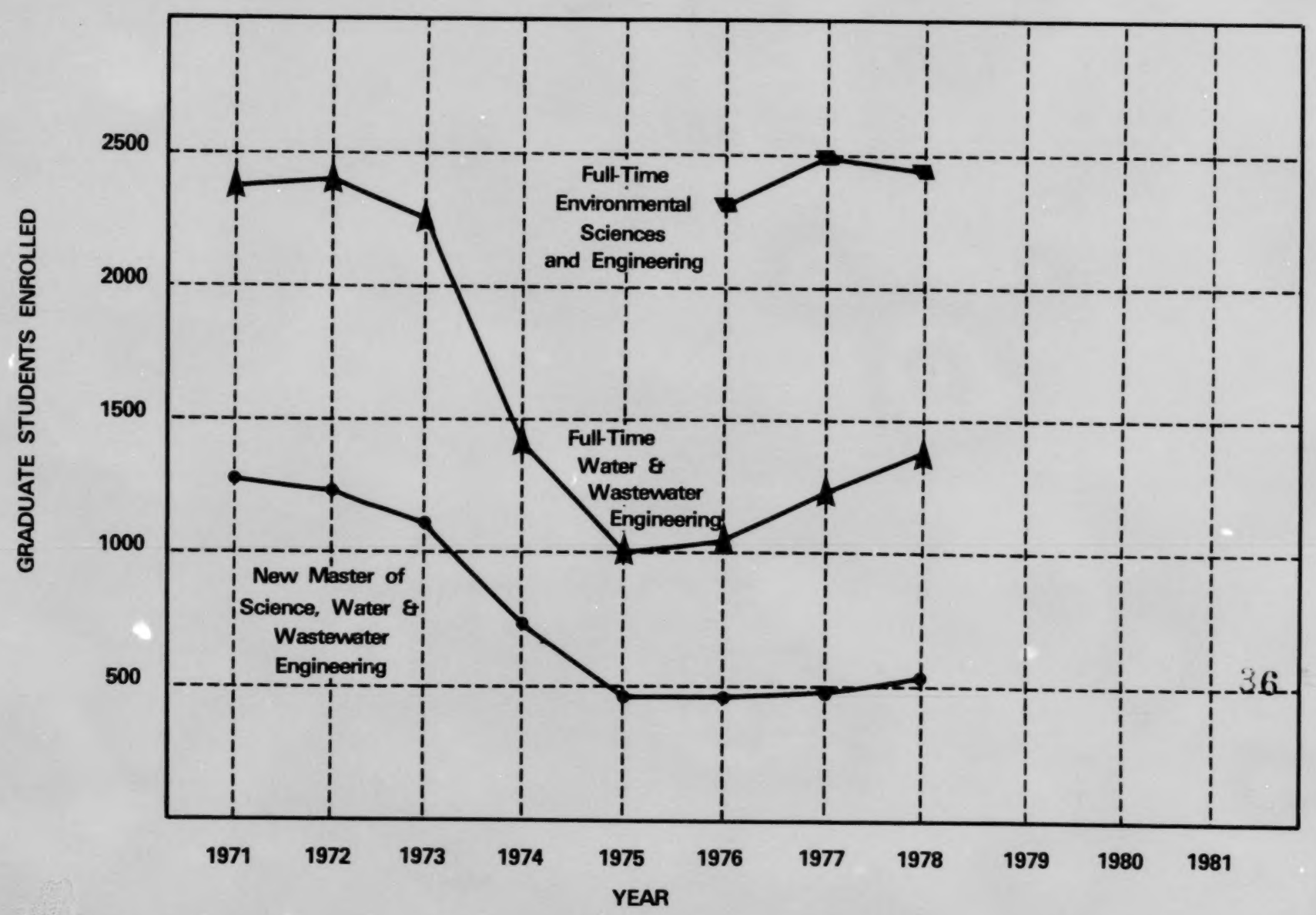


Table III
Water Pollution Training Activities Support by EPA
Involving Academic Institutions

Activity	Fiscal Year								
	1972	1973	1974	1975	1976	1977	1978	1979	1980
Grants to Universities									
Funds ($1000)	4650	5937	3574	2174	2121'	420"	490"	240"	160
Number of schools involved	103	108	65	52	38	36	38	29	-
Number of trainees supported									
Technicians	0	0	0	0	0	0	0	0	-
Bachelor's level	0	135	130	130	227	41	82	20	-
Master's level	1295	1001	876	595	462	93	92	46	
Doctoral level	0	0	0	0	0	0	0	0	-
Total	1295	1136	1009	705	669	134	174	66	-
Fellowship Training									
Funds ($1000)	0	0	230	338	394*	154**	310**	170**	125
Number of trainees									
State & local agency-full-time	0	0	38	52	48	22	30	15	
State & local agency-part-time	0	0	0	21	49	36	71	35	-
Other trainees	0	0	0	0	0	0	0	0	-
Total	0	0	38	73	97	58	101	50	-
Total Funds ($1000)	4650	5937	3804	2512	2515	574	800	410	-

' $735K was from Congressional add-on
" All from Congressional add-on
* $50K was from Congressional add-on
** All from Congressional add-on

enrollment by developing funded research that supports students and by catering to part-time evening students. However, withdrawal of federal support has inevitably had a devastating effect on productivity.

Environmental problems have proliferated during the years since EPA decided to phase out its graduate training support program. Nevertheless, the output of graduates from the schools has been markedly reduced during this period. From a high of about 2400 in 1972, the number of Master's level graduates with environmental engineering specialties plummeted to 1000 per year by the middle of the decade. The number of new M.S. students in wastewater engineering fell dramatically from 1200 in 1972 to only 400 in 1976, a distressing 68% drop. These precipitous decreases are illustrated in Figure 2 taken from an analysis by William Jewell published in the Journal Water Pollution Control Federation in 1978 (p. 607).

There has been some tentative and partial recovery since 1976, and the number of graduates in 1978 (the most recent year for which data are available) reached about 1400--still little more than half the level of the early 1970s. Thus, the enrollment history illustrates a serious concern: as the federal government has increasingly bowed out of the training of environmental human resources, the private sector has failed to take up the slack.

The National Research Councils' Committee on Sanitary Engineering and the Environment recognized the broadening scope of sanitary engineering or, as some began to say "public health engineering," by their definition, first developed in 1943 and subsequently revised in 1954 and 1957. The 1957 revision was the outgrowth of a conference on "Education, Training and Utilization of Sanitary Engineers" held under the auspices of the subcommittee on Personnel and Training. Abel Wolman was chairman of the parent committee and Earnest Boyce, chairman of the subcommittee.

The 1943 definition stated that a sanitary engineer was an engineer "who has fitted himself by suitable specialized training, study, and experience to

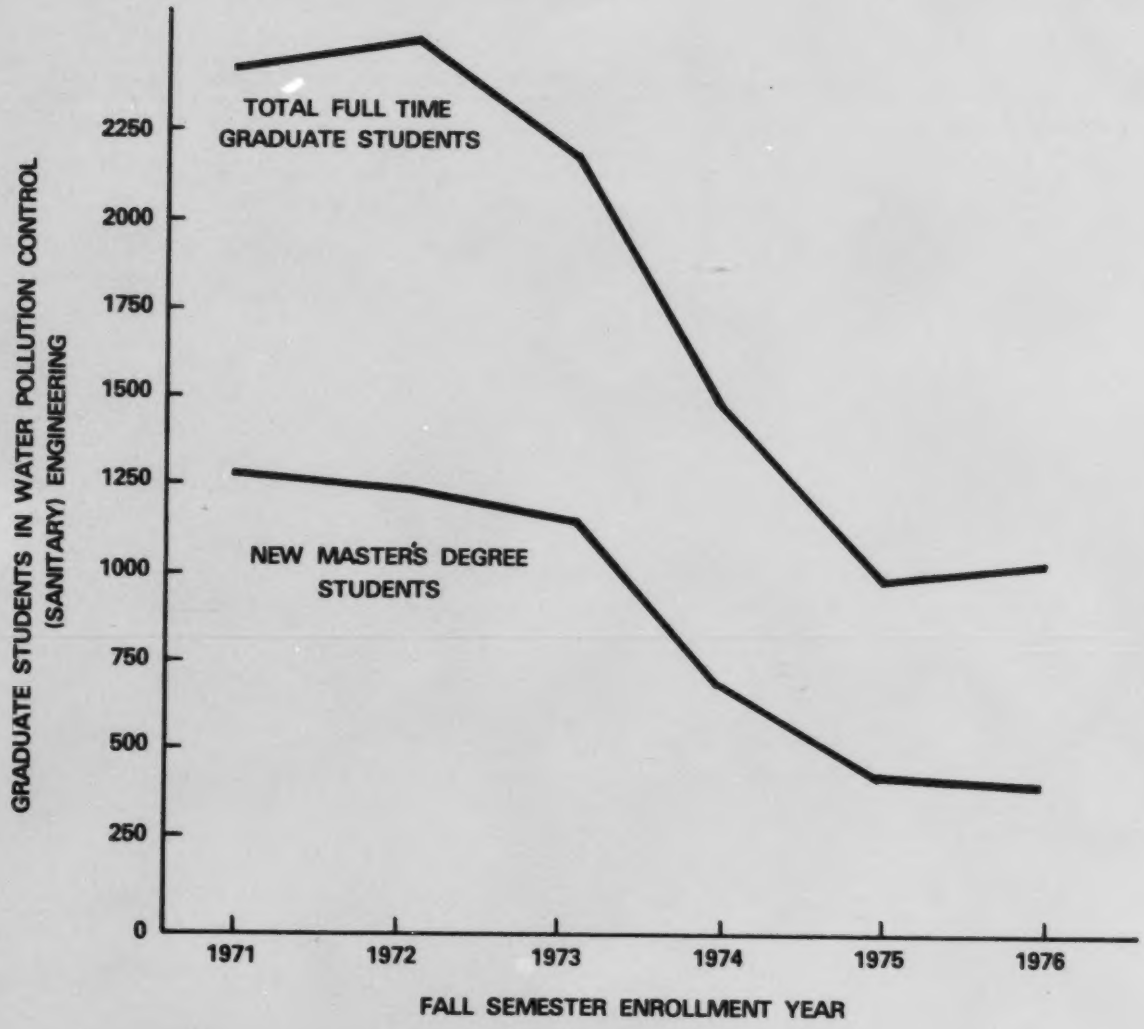


FIGURE 2. SUMMARY OF GRADUATE ENROLLMENT IN THE WATER POLLUTION CONTROL ENGINEERING FIELDS SINCE 1971 (JOURNAL WATER POLLUTION CONTROL FEDERATION)

(a) conceive, design, appraise, direct and manage engineering works and projects developed, as a whole or in part, for the protection and promotion of the public health, particularly as it relates to the improvement of man's environment, and (b) to investigate and correct engineering works and other projects that are capable of injury to the public health by being or becoming faulty in conception, design, direction or management". The statement refines this definition by enumerating the following activities:

1. "Surveys, reports, designs, reviews, direction, management, operation, and investigation of works or programs for:

   a. Water supply, treatment and distribution.

   b. The collection, treatment, and disposal of community wastes, viz., sanitary sewage, industrial wastes, and refuse, including salvage and reclamation of useful components of such wastes.

   c. The control of pollution of surface waterways and ground waters, and of surface and subsurface soils.

   d. Milk and food sanitation.

   e. Housing and institutional sanitation.

   f. Insect and vermin control or eradication.

   g. Rural, camp, and recreation place sanitation.

   h. The control of atmospheric pollution and air quality, and of light, noise, vibration and toxic materials, including application to work spaces in industrial establishments (industrial hygiene engineering).

   i. The prevention of radiation exposure.

   j. Other fields that have as their major objective the control of environmental factors affecting health.

2. Professional research and development work supporting the activities listed in 1.

3. Responsible teaching of sanitary engineering subjects in educational institutions of recognized standing."

A significant conclusion of the 1957 report was a recommendation that the four year undergraduate curriculum in civil engineering, implied by the definition, be followed by a fifth year leading to a Master's degree. The conference also concluded that the four-year undergraduate specialization in sanitary engineering failed completely to supply enough sanitary engineering graduates to meet the demand and found that options in civil engineering were frequently deficient in biology and chemistry.

Impact of National Conferences

A series of national conferences has focused attention on manpower demands for environmental engineering and on how to meet the emerging challenges of environmental issues through education.

1957 NRC Conference

This conference called for a core of courses including environmental hygiene, engineering statistics, and epidemiology. Areas of specialized education were (a) public health, (b) water works and waste disposal works, (c) industrial hygiene, (d) radiological health, and (e) air pollution control. It was noted that civil engineering graduates would be best for specialties related to public works, but mechanical and chemical engineers would be better qualified in such areas as air pollution and industrial hygiene. The conference recommended that traineeship and fellowship programs be expanded and extended, particularly in specialized fields at the postgraduate level.

1960 Harvard Conference

With a grant from the National Science Foundation, the American Sanitary Engineering Intersociety Board (ASEIB) sponsored a Study Conference on Graduate Education of Sanitary Engineers at Harvard University in June 1960. About 100 sanitary engineers and scientists were invited from education, industry, consulting, public health and public works agencies to discuss means for raising the educational standards of the sanitary engineering profession and for meeting the diverse requirements for sanitary engineers.

The conference focused on the special areas of water resources engineering, air resources engineering, and public health engineering, as well as basic science educational requisites.

The conferees recommended the Master of Science from programs accredited by the Engineers' Council on Professional Development as the first professional degree. They were concerned that the undergraduate sanitary engineering options in civil engineering did not provide adequate preparation for professional careers in sanitary engineering.

The conference recommended that Master's programs be one calendar year and contain a common core of chemistry, microbiology, radiological hygiene, statistics and epidemiology. Confusion in the use of terms, such as "sanitary engineer", "industrial hygiene engineer," "public health engineer," and "environmental health engineer" led to a recommendation that ASEIB study the question of terminology.

1962 Airlie House Conference

The National Research Council, at the request of the Public Health Service, invited educators and others to meet at Airlie House in June 1962 to consider the broadening horizons of environmental health and the growing concern of society for control of environmental hazards. This conference addressed in particular the institutional, professional and intellectual impediments to recruitment and more effective graduate training for service in environmental health.

The conference identified manpower deficiencies in the following terms:

> "There does not exist in the United States an important roster of highly qualified scientists and technologists primarily concerned with environmental health. It is difficult to rectify this situation within the present pattern of support and training in environmental health. When one views the current state of the art against the panorama of problems and responsibilities that face the United States today, the conclusion seems inescapable that a major academic effort is required."

The conclusions of the conference placed primary emphasis on the need to establish "academic centers of environmental health."

1967 Northwestern Conference

The Second National Conference on Environmental and Sanitary Engineering was held at Northwestern University in August 1967. Special areas of concern included municipal and industrial water and wastewater, air pollution, industrial hygiene, and solid wastes.

The Northwestern Conference confirmed that the term environmental engineer was the appropriate generic term. Sanitary engineering was equated to water quality engineering. Other areas of special concern to environmental engineers included air pollution, industrial hygiene and solid waste management. A new designation -- urban environmental engineer -- was suggested for those concerned with environmental aspects of transportation, building design and urban planning. A working definition of environmental engineering was declared to be "...that branch of engineering that involves the application of scientific principles to the prevention, control and management of environmental factors that may influence the physical and emotional health of man and his well-being."

The conference recognized the participation of environmental engineers in multidisciplinary teams. Special attention was given to environmental engineers' preparation in chemistry and biology. For a leadership role in management of environmental systems and programs, knowledge of social sciences was deemed necessary.

It was suggested that educational programs should provide specialists in the traditional civil-sanitary role for municipalities interfacing public works and urban planning. Educational programs also were needed to meet the needs of the newer environmental engineering activities and to anticipate the environmental effects of proposed activities; plan, organize and conduct environmental programs; become involved in the study of environmental engineering aspects of land use, urban rehabilitation and urban planning; and recognize the interrelationships with other disciplines. Specific suggestions were made for appropriate curricula.

1973 Drexel Conference

The six years intervening between the Northwestern Conference and the Drexel Conference of August 1973 was a period of dramatic change in public awareness of environmental issues and responses of society to these challenges to human health and well-being and vitality of natural ecosystems as mentioned earlier.

Interest was not confined to the United States. The United Nations held the Conference on the Human Environment at Stockholm just one year before the Drexel Conference. It focused world-wide attention on environmental issues.

The 1973 conference, like its predecessor, was sponsored by the American Academy of Environmental Engineers and the Association of Environmental Engineering Professors. Financial support was provided by EPA. Some funds were also made available from a W.K. Kellogg Foundation grant to Drexel University for development of environmental management programs.

This conference developed the broadest concept to date of environmental engineering, which it defined as follows:

> "Environmental Engineering is that branch of engineering which is concerned with the application of scientific principles for
>
> (1) the protection of human populations from the effects of adverse environmental factors
>
> (2) the protection of environments, both local and global, from the potentially deleterious effects of human activities, and
>
> (3) the improvement of environmental quality for man's health and well-being."

The conference developed curricula suggestions in the conventional areas of air quality engineering, water quality engineering, industrial hygiene engineering, and solid waste management. But more importantly, the impact of emerging societal problems was considered and their implications for environmental engineering education assessed. Issues considered were population pressures, energy systems, land use planning, urban and regional development, the "built" environ-

ment, transportation and product quality. (These issues certainly came to the fore in the 1970's, some as "crisis" issues.) While environmental engineering was not considered to be the profession to provide primary leadership in these areas, it was concluded that environmental engineering education should deal with these issues in a way that environmental impacts might be properly assessed and handled.

A controversial development was recognition of the soundness of instituting a completely new undergraduate curriculum in environmental engineering and encouragement of further development. Since the conference, the Academy, professors and ASCE have developed criteria for accreditation of undergraduate degrees, particularly civil and chemical. An undergraduate degree designed to meet the exclusive needs of environmental engineers was considered more efficient than teaching the subject as a sub-discipline of other branches of engineering. Even with specialized undergraduate programs, however, the Conference still felt that adequate preparation for professional jobs would continue to require graduate training at least to the Master's level.

Manpower requirements to implement new legislative initiatives were examined. In light of the forecasts, manpower production for air and water pollution was judged inadequate to meet the needs. Federal financial support for graduate and undergraduate education was urged.

An ominous note was sounded, which has since become alarming. It was pointed out that we were reaching the limits of technology for solving many problems. Thus it was recommended that educational programs be tied in with expansion of research so that technically and scientifically sound, economically feasible, and socially acceptable solutions could be found.

Chapter 3
Categories of Manpower

Manpower Users

Concern for the environment in which we live has heightened greatly in recent years. It has become more and more apparent that improved water quality and better environmental conditions go hand-in-hand: it is not possible to have one without the other. As a result, the demand has grown for people trained to deal with the many problems of maintaining and improving such quality. At the same time, there has been a tremendous growth in the number of organizations and areas with a need for qualified technical personnel.

A fully detailed list of water quality/environmental quality users would serve no particular purpose here. Each passing day, with its new scientific and technological discoveries, increases the need for skilled environmental personnel, already in short supply. Instead of preparing a long and burdensome list, of the kinds of personnel needed, it would appear more meaningful to examine a small number of the proven user-groups with appropriate brief comments on manpower-related aspects of their areas of responsibility.

Industrial and Commercial

This category covers a great variety of manpower requirements. An incoming employee may need highly specific additional training and experience before being fully capable of performing a specific and specialized job. The comment is heard from some employers in this area: "We have to train the person on-the-job before getting our money's worth." The fact remains that a properly-educated scientist or engineer comes to any job, in his area of competency, prepared to assimilate without delay the required details in order to provide satisfactory performance within a short time span.

The Committee for Study of Environmental Manpower (CSEM) of the National Academy of Sciences observed in its 1977 report that the private sector is involved in water quality control in various ways. Among such employers, planning activities are expected to increase greatly; more effective techniques for design of facilities will be needed and facility design and construction will require expertise normally not possessed by general contractors. Equipment design, fabrication and operation and maintenance, as well as research and development can be expected to share the demand for manpower. Educational institutions at all levels, providing degrees from two year to doctoral, will be called upon to meet the demand.

Federal Government

Federal agencies are employers of substantial amounts of manpower concerned with water quality, either directly or indirectly. EPA is the largest but almost all major agencies have some involvement in maintaining or improving environmental quality and that of its critical constituent, water.

The government exerts a strong influence throughout the nation on behalf of water quality control. Federal influence is felt not only through employment channels but also in the pursuit of its legal responsibilities involving water quality. Other activities of note include dispensation of support funds to state and local agencies, initiation of various programs affecting the foregoing, drafting of regulations and conducting enforcement actions, establishing demonstration projects, and a host of other programs.

State Government

Some states, for reasons related to such factors as population pressure, aggressive leadership and financial soundness, are in a better-than-ever position to assume increased responsibility for planning, activating and enforcement activities. Others seem to have a preference for leaving such matters to be handled by federal action. EPA has expended considerable amounts of energy and funds in analyzing state programs for water quality improvement as well as state capabilities to meet major regulatory and enforcement requirements assigned by existing legislation.

Despite the difficulty of predicting accurately the personnel numbers required for future state programs, it is reasonable to conclude that greater numbers will be needed in the future. What may be even more important is the clear need for upgrading the technical qualifications of existing staffs, plus the acquisition of additional people who possess advanced educational backgrounds relevant to the job at hand.

Local Government

The capacity of local government is questionable in the area of construction and operation/maintenance of water quality control facilities. This factor is recognized in a study by the Subcommittee on Urban Water Supply on capital replacement and rehabilitation needs of urban water systems across the nation. The study provides an estimated cost as high as $80 billion. Federal consideration of encouragement and support for such an effort is most likely to result.

There are more than 62,000 local government entities bearing various degrees of responsibility for water quality control. Even though a wide degree of latitude is to be found in the anticipated expenditures in this area, appreciable requirements will be generated for technical manpower. Among the problems confronting the numerous localities is that of storm-water management, which can exert a significant influence on water quality and the performance of wastewater treatment facilities. This means appreciable future expenditures and increased manpower needs for planning, design, construction and operation/maintenance. An indication of the magnitude of funds involved is provided by the 1975 and 1976 Council on Environmental Quality annual reports, which estimated state and local operation and maintenance costs for water pollution control in 1983 at slightly over $3 billion per year and more than $6 billion in 1984. Inflationary increases since 1976 must be added to these figures.

Educational Institutions

The generally non-competitive salaries at educational institutions are discouraging entry of qualified environmental engineering instructors, despite the

increasing need for trained environmental engineers. Lack of financial support discourages the advanced training necessary to produce qualified teachers.

Consulting Organizations

These sources of potential employment are important. They are effective in competing with other categories of employers for high-quality personnel. Though their total needs are not numerically great, the criteria they use in selecting personnel provide useful curriculum guidelines for educational institutions. However, the relatively high salaries that consulting organizations pay to engineers without graduate education may discourage many able bachelor-level graduates from pursuing advanced training. If the colleges and universities are to devote time and energy to developing forward-looking programs, the federal government must fulfill its recognized responsibilities for bearing a part of the financial burden in support of such education and training efforts.

Manpower Types and Qualifications

This section will be concerned with professionally-trained personnel having educational qualifications gained through study at not less than two year colleges resulting in associate-type degrees as well as universities offering baccalaureate and postgraduate programs. It was decided to make a limited staff analysis of two major organizations concerned with water quality control--one in the eastern United States, Washington Suburban Sanitary Commission(WSSC) serving suburban Maryland in the vicinity of Washington, D.C.; the other in the west, County Sanitation Districts of Los Angeles, California (CSD).

The purpose of this analysis can be met without going into detail on such factors as "example of duties" and "desirable qualification," found in all position descriptions. Here, we are concerned basically with the range of professional jobs requiring degree-level education needed to staff water quality control organizations. The levels included are associate, bachelor, master, and doctor. Table IV includes total, full-time, occupied positions related to water quality.

Table IV : Full-time, Occupied Water Quality Positions at WSSC and CSD*

Title	Type of Responsibility	Knowledge Required	Academic Degree/ Certification
Chief Engineer and General Manager Assistant Chief Engineer & Assistant General Mgr	Managerial, policy and decision-making	Sanitary, civil and related fields. System design, construction and operation	State certificate of registration as professional engineer
Information Officer	Direction of program advising the public and professionals or organization's activities	Principles and techniques of environmental engineering, major communications media and public relations	M.S. in civil or related engineering field; or 4 years' professional engineering experience and state Engineer-in-Training certificate
Assistant Information Officer	As above but to lesser degree	As above but less broad	Same as above with only 2 years' experience in engineering required
Departmental Engineer (Principal Engineer)	Place, organize, coordinate and direct a major engineering department	Sanitary, civil and related engineering fields as applicable to design, construction and operation of facilities	Education meeting state professional engineering registration requirements or 5 years supervisory experience
Assistant Departmental Engineer (Sr. Engineer)	As above but to lesser degree	As above but less broad	Certificate of Registration as above or 4 years supervisory experience
Departmental Engineer Assistant (Engineer I)	Assists above 2	As above but less broad	Same as above but 3 years experience
Division Engineer II	Plan, organize, coordinate and direct work of an engineering division	Principles of supervision and training; engineering principles, practices, techniques development and method	3 years supervisory experience in class requiring registration as professional engineer. Possession of certificate of registration

Title	Type of Responsibility	Knowledge Required	Academic Degree/ Certification
Division Engineer I	Similar to II but less supervision and coordination exercised	Same as Engineer II	Same as II
Supervising Civil Engineer	In charge of major engineering design work or engineering pilot studies. Performs as Project Engineer on large, complex assignments	Wide range of disciplines from principles and practice of civil engineering to engineering economics and stress analysis	B.S. in engineering and 6 years experience or M.S. and 4 years of civil engineering experience, or Ph.D. in engineering and 3 years experience
Civil Engineer	Variety of the most complex and professional civil engineering work. Also, supervise project design activities	Principles, materials and practices of civil engineering. Fundamentals of applied research, hydraulics and uses of construction material	Only slightly less stringent than Supervising Civil Engineer. Experience required reduced in each category by 1 year
Engineering Associate III	Performs fully qualified design, inspection, operations, evaluation and research work	Fundamentals of engineering construction techniques. Investigation procedures, research and survey methods and equipment design	Possession of state registration certificate desirable 4 years professional engineering experience. M.S. degree may be substituted for 2 years experience
Engineering Associate II Engineering Associate I	Same as above but lesser degree	Generally same as above. Differences are based on degree of supervision received and abilities required	Essentially as above but with less experience required. In I, B.S. (Eng) may be substituted for certificate of Engineering-Training
Supervising Mechanical Engineer	Supervise project and design engineers. Direct and coordinate work on treatment plants, pumping stations and related activities	Principles and practices of mechanical engineering. Safety codes and orders applicable to mechanical installations	B.S. in engineering and 6 years professional mechanical engineering experience. Years reduced to 4 with M.S. and to 3 with Ph.D. State Certificate of Registration

List of Positions

Title	Type of Responsibility	Knowledge Required	Academic Degree/ Certification
Mechanical Engineer	Same as above but exercises less supervisory responsibility	Same as above but to lesser degree	Same as above but with slightly less experience
Electrical Engineer	Designs and prepares specifications plans and cost estimates for power installations and control systems	Electrical theory and practice, codes, safety orders and equipment used in electrical construction. Includes circuit design, power, light and control distribution systems	State Certificate of Registration as professional electrical engineer. Same degrees and experience as supervising mechanical engineer
Instrumentation Engineer	Performs system design and evaluation for regulation, operation and monitoring of various facilities such as pumping and water treatment plants	Fundamental hydraulics, instrumentation theory and practice, electronic circuit design and application of computer science in control systems	State Certificate of Registration as a professional engineer. Same degrees and experience as above engineers
Supervising Environmental Scientist	Plans, organizes and directs major scientific studies. Compiles and submits reports	Principles of water resource research, environmental ecology, and effects of various materials on water quality and the biota	B.S. degree in appropriate scientific discipline and 2 years of increasingly responsible supervisory experience
Environmental Scientist	Same as above	Same as above but less supervisory practice	Same as above except experience in environmental research rather than supervision
Associate Environmental Scientist III	Perform scientific studies, emphasizing non-engineering disciplines of the marine environment and research on water treatment processes	Fundamentals of chemistry, physics and biology with detailed understanding of scientific research, investigatory methods and statistical procedures	B.S. degree in appropriate discipline. M.S. degree may be substituted for 2 years of experience

List of Positions

Title	Type of Responsibility	Knowledge Required	Academic Degree/ Certification
Associate Environmental Scientist I and II	Same as above but lesser degrees of difficulty	Same as above	B.S. degree as above but less experience required
Supervising Biologist	Supervises and participates in work of subordinate biologists and laboratory technicians		
Biologist	Similar to above but supervision generally limited to laboratory technicians	Same as above	Same as above except for requirement of supervisory experience
Supervising Microbiologist and Microbiologist	Similar to biologist series except for dealing with specialized analysis of viruses, pathogenic bacteria, parasites and various microbiological techniques	Microbiological principles including bacteriology, mycology and parasitology. Required laboratory techniques equipment, materials and terminology	Same as biology series except for specialty differences
Superintendent of Laboratories Assistant Superintendent of Laboratories	Direction of research and control laboratories. Assistant differs only in degree and extent of responsibility	Principles of chemistry, bacteriology, biology and physics; laboratory procedures, techniques and equipment	6 years of increasingly responsible professional experience in laboratory work with 3 years in supervisory capacity. Assistant essentially same. M.S. degree in biology, chemistry or related science may be substituted for 1 year of experience

* This listing is derived from data provided by the Washington Suburban Sanitary Commission and the County Sanitation Districts of Los Angeles

The above table is not intended to be complete but rather to illustrate the rigorously high standards maintained in two highly-considered quality organizations. It is fully recognized that there are many systems which are understaffed, both as to capabilities and numbers of water quality control personnel.

Furthermore, numerous additional positions exist in the two organizations listed above (WSSC and CSD), which require a college or university education and are concerned with water quality control. Publications of the Water Pollution Control Federation and the American Water Works Association disclose use of the following additional titles:

Title of Position	Title of Position
Laboratory Supervisor I and II	Senior Industrial Waste Inspector
Senior Laboratory Technician	Industrial Waste Inspector I and II
Laboratory Technician I and II	Industrial Waste Surcharge Supervisor
Supervising Chemist	Industrial Waste Surcharge Assistant, I, II, III
Senior Chemist	Principal Engineer
Chemist	Senior Engineer
Supervising Systems Analyst	Project Manager(Engineer) I,II,III
Systems Analyst I and II	Planning Manager III, II, I
Data Processing Manager	Contract Manager(Engineer/Technician) III, II, I
General Superintendent of Joint Water Pollution Control Plant	Senior Plant Superintendent
	Plant Superintendent
Assistant Sewage Treatment Superintendent	Assistant Plant Superintendent
Supervising Industrial Waste Engineer	Water Supply Section Head
Industrial Waste Engineer	Assistant Water Supply Section Head
Supervising Industrial Waste Inspector	Legal Counsel

Conclusion

Certain factors in the manpower picture are apparent from this brief analysis:

1. There is a wide variety of users for professional personnel in the field of water quality control across the nation;

2. As regulations become more stringent and previously unknown polluting elements are discovered in water supply sources and industrial effluents, control strategies become more and more difficult to implement. This places an ever-increasing burden on our educational institutions. Any measure that assists educational institutions in doing the job will serve the public interest.

Chapter 4
The Basic Reasons for Concern About Water Quality

Human health is the preeminent problem facing water quality control personnel as we enter the 1980's. During the past two centuries, environmental controls have been one of the chief factors behind the spectacular lowering of death rates. Medical advances have played only a minor role. In January of this year, Dr. Norman Brachfeld of Cornell University cited statistics from England and Wales indicating that since 1848 specific drug treatments or vaccines have accounted for only one quarter of the drop in the death rate from a variety of diseases transmitted by the respiratory route. His list included tuberculosis, bronchitis, pneumonia, influenza, whooping cough, measles, scarlet fever, diphtheria and smallpox. In the United States the life expectancy of a newborn baby today is 30 years longer than it was in 1900. The trend in death rates continued in the 70's with a drop of 0.63 deaths per thousand or 6 percent in the period of 1973 through 1977. Dr. Brachfeld noted that environment, behavior and nutrition have far more effect on health and death rates than the 140 billion dollars that the United States spends each year on most treatment-oriented medical cures. Thus, the environmental engineers, social reformers, and humanitarians have played a major role in the struggle against death and the suffering of mankind in the 19th and 20th centuries.

The leading causes of death in our population have changed in recent years. As infectious diseases have been controlled, increasing numbers of our population succumb to chronic diseases. The death rates for the three leading causes of death in the United States during 1975 may be found in Table V.

Table V

Rank	Cause of Death	Death Rate	Percent of Total
1	Diseases of the heart	339.0	37.8
2	Malignant neiplasms, including neiplasus of lymphatic and hematopoictic tissues	174.3	19.5
3	Cerebrovascular disease	91.8	10.2
		605.2	67.5
	All Causes	896.1	100

Thus, 67.5 percent of the death rate is currently represented by three chronic diseases. Therefore, water quality control personnel must broaden their interests and abilities to include chronic as well as infectious disease. For example, the current interest in determining the epidemiological symptoms and the need for removing cancer-producing substances from our drinking water is an appropriate area of work.

The magnitude of the toxic substances problem is difficult to quantify. In November 1977, the registry of chemicals maintained by the American Chemical Society listed 4,039,907 distinct chemical compounds, which includes only compounds reported in the literature since 1965. The list has been growing at a rate of 6000 compounds per week. Seventy thousand of the compounds listed are currently in commercial production in the United States. The environmental and health effects of most of these substances have not been adequately studied. A massive screening effort by water quality personnel is needed now to avoid the chronic effects of many of these substances on our population.

The major concern at this time with the health effects of these substances is their potential relationship to cancer. This emphasis may reflect a mistake in priorities when one considers that the elimination of all cancer would extend the life expectancy of a new-born about 2.3 years. In contrast, eliminating all heart, blood vessel, and related kidney diseas would add

approximately 18 years to a baby's life expectancy. It has been demonstrated that carbon monoxide and cadmium may be related to various heart and cardiovascular diseases. Further research with other toxic substances and their possible linkage with heart and cardiovascular diseases is definitely needed now by water quality control personnel.

It is apparent that the preparation of new water quality control personnel must change to respond to these changing needs. In addition, existing personnel must also be retrained.

It should also be noted that the demand for and the numbers and preparation of water quality control personnel does not respond predictably to the marketplace, but rather is controlled to a major extent by federal and state legislation. The citizens of the United States have expressed their desire for a healthy safe and clean environment through the enactment by Congress of numerous laws. A list of federal legislation pertaining to environmental protection is presented in Table VI.

The increased concern of our population may be illustrated by observing that twenty-two separate pieces of federal legislation have been passed in the last ten years while only six were enacted in the preceding seventy years. The full implementation of the recent legislation has not progressed smoothly and in numerous cases legislated deadlines have not been met. It has become increasingly apparent that one major problem that has handicapped the water quality control effort in this country is the unavailability of a skilled workforce to respond effectively to the needs of people.

Thus, the professional community has become increasingly concerned with the numbers and the preparation of water quality control personnel.

Uncertainty in Census of Existing Personnel

Water quality control activities include a diverse occupational mix. As indicated in the preceeding chapter, the technical component of this mix includes

Table VI

Legislation Pertaining to Environmental Protection

DATE	PUBLIC LAW	TITLE
1899	33USC 401-413	Rivers and Harbors Act
1964	PL88-379	Water Resources Research Act of 1964
1965	PL89-80	Water Resources Planning Act of 1965
1966	PL89-665	National Historic Preservation Act of 1966
1967	42USC 7401 amended by PL90-148	Clean Air Act (amended in 1970-73-74-77)
1968	PL85-624	Wild and Scenic Rivers Act (amended in 1972-74)
1969	PL91-190	National Environmental Policy Act of 1969(NEPA)
1970	PL92-574	Occupational Safety and Health Act
1971	PL85-264	Fish and Wildlife Coordination Act
1972	PL92-340	Ports and Waterways Safety Act of 1972
	PL92-516	Federal Pesticide, Fungicide & Rodenticide Act (amended in 1975-78)
	PL95-87	Surface Mining Control & Reclamation Act of 1972
	PL92-532	Marine Mammal Protection Act (amended 1973)
	PL92-500	Federal Water Pollution Control Acts Amendments of 1972 (amended in 1974-75-76 and 1978)
	PL92-574	Noise Control Act of 1972 (amended in 1976)
	PL92-532	Marine Protection, Research and Sanctuaries Act of 1972
	PL92-583	Coastal Zone Management Act of 1972 (amended in 1976, 1978)
1973	PL93-205	Endangered Species Act (amended in 1976-77)
1974	PL93-577	Non-nuclear Energy Research and Development Act of 1974
	PL93-523	Safe Drinking Water Act (amended in 1977)
	PL93-319	Energy Supply and Environmental Coordination Act of 1974
	PL93-627	Deep Water Port Act of 1974
1975	PL89-272	Resource Conservation and Recovery Act of 1976 originally PL89-272 of 1965; amended in 1970-73-75-76)
	PL94-469	Toxic Substances Control Act (TOSCA)
1977	PL95-192	Soil and Water Resources Conservation Act of 1977
	PL95-91	Department of Energy Organization Act of 1974
1978	PL95-604	Uranium Mill Tailings Control Act

engineers engaged in design, construction and operations; scientists, particularly biologists and chemists, working on research, development and operations; technicians employed for drafting, laboratory testing and operations; and managers. In addition, there are large numbers of trade workers, plant operators, clerical and service personnel and laborers included in the above activities. To date a truly comprehensive census of water quality personnel has not been made. The most recent independent attempt was made by the National Field Research Center, Inc. and is not complete. For example, the Massachusetts portion of the report entitled "A National Environmental/Energy Workforce Assessment" lists a total of seventeen position titles in the potable water area and one hundred eleven in the wastewater area for 1976. It was noted that their data "include only state agency personnel" in these categories. The best comprehensive estimate to date was published in 1977 by the National Academy of Sciences (NAS). The Academy examined a large quantity of sometimes inconsistent data on current employment of pollution control manpower. The data on scientists and engineers were based on the 1976 NSF National Survey of Scientists and Engineers. The data on technicians, skilled operators, and unskilled clerical and other categories were based on a synthesis of material from various public sources, including EPA, NSF, Bureau of the Census, and Bureau of Labor Statistics. One primary limitation noted was that the 1974 NSF counts of scientists and engineers excluded post-1970 entrants to the science and engineering labor force. The NAS report indicated, therefore, that their numbers for these categories "should be considered an approximation of the numbers of people engaged in the activity rather than a precise census count." Thus, there is no recent census of water quality control personnel.

Uncertainty in Current Manpower Projections and Techniques for Making Predictions

In September 1978, an article by George J. Schroepfer entitled "A Philosophy of Water Pollution Control -- Past and Present" was featured in the Water Pollution Control Federation Journal. In this article Schroepfer echoed the opinion of many professionals working in the field of water quality control that "there

is a real shortage of sanitary engineers in all areas." While these opinions are based on experience rather than studies, they should be an important element in estimating future manpower needs. A number of environmental manpower surveys, including those by Middlebrooks and by Moeller, have also predicted general shortages. The most extensive survey to date, the National Academy of Science report on Manpower for Environmental Pollution Control (1977) mentioned above, concluded that there will be no overall shortage, but predicted spot shortages in specialized areas. One estimate projected that an additional 8000 engineers would be required by just the public sector by 1985 in the wastewater area alone. The report estimated a minimum overall increased need by that date of 16,000 professional engineers. The NAS report recommended (page 383):

> "To assure that there will be available professional, technical and operational personnel needed....it is recommended that the Federal government encourage and financially support substantially increased academic and other personnel training programs without further delay".

The numerous projections concerning manpower needs in the field of water pollution control are of limited use. Several of these published manpower projections have been based on surveys of prospective employers regarding their future hiring plans and anticipated employment opportunities. The results of these studies are based on the individual respondent's perception of present and future economic conditions. Thus an analysis of these replies may at best provide an appraisal of future manpower needs in the short run during periods of relatively stable economic, fiscal and political conditions. In addition, there have been other efforts such as the Bureau of Labor Statistics (BLS) 1971 report on "Tomorrow"s Manpower Needs" which used the following assumptions about the economy:

1. International climate will improve;
2. Institutional framework of the American economy will not change radically;
3. Economic, social, technological and scientific trends will continue;

4. Fiscal and monetary policies will achieve a satisfactory balance between low employment rates and relative price stability;
5. All levels of government will join efforts to meet a wide variety of domestic requirements;
6. Problems posed by air and water pollution and solid waste disposal may require an increasing amount of the nation's productive resources but will not significantly dampen our long-run potential rate of growth.

These assumptions have become increasingly problematic in light of events since 1971.

Actual conditions during the past decade have been neither stable nor consistent with the six assumptions made in preparing the BLS report. During this period, we experienced an oil embargo and greatly increased energy costs, two recessions, periods of inflation, several international crises, lowered government funding for research and development after 1969 (measured in constant dollars), and lagging funding for water pollution control facilities. Thus, there is considerable uncertainty in current projections for needed numbers of water quality control personnel.

Consequences of Faulty Projections in Terms of Under- and Over-Supply of Personnel

Past faulty projections of the numbers of water quality control personnel needed in the future have not created an over-supply of workers. This lack of response is a consequence of the fact that the free market does not function normally in the case of the environment workforce. Thus, projections of either under- and/or over-supply of water quality personnel are not likely to greatly influence the size of the available workforce in the future nor the full implementation of the water quality control program. This does not mean, however, that projections should not be made. The success of the water quality control program and the continuing health of our population is dependent on good projections of the need and supply of manpower and the use of these projections to manage our water quality personnel workforce. EPA should assume responsibility for making such surveys.

According to the National Academy of Sciences, "Although scientists and engineers make up less than two percent of the employed civilian labor force they represent fully a fifth of those employed directly in pollution control activities." We must know of the needs for highly trained personnel in specific activities and the available supply because of the large fraction of the environmental workforce they represent. This information must then be used to provide the required personnel where needed. An insufficiency of trained personnel will have a severe impact on the people of our country in terms of shorter lives with more illness. The consequence of an over-supply of trained personnel would be nominal in comparison, since any excess workers have the opportunity to move into a new field for jobs.

Impact of EPA and Other Federal Program Variations in Funding

The federal government exerts a primary influence in the field of water quality control because of the heavy regulatory and financial support role it has assumed. Its ability to cause massive shifts in resources from one program to another in a short time provides the federal government with a unique capability to accomplish goals of enhanced environmental quality. On the other hand, this ability to quickly alter priorities and resource allocations for a wide variety of discretionary programs, such as the nation's energy needs may actually endanger the environmental program. The priorities established by the federal government are a major determinate of the demand for manpower in the environmental field. Thus, any shift in priorities away from water quality would reduce the active demand for water specialists, even though the actual need for such specialists would be unchanged. Thus, the impact of the federal government is probably the single greatest key factor determining our nation's future environmental needs.

Chapter 5
Pilot Test of a Panel-type Survey

In the course of its attempts to define the human resources situation in the water pollution control field, AAEE decided to conduct a limited survey of individuals with special knowledge of manpower problems. An extensive and detailed survey was not feasible nor, as explained later in this chapter and in Appendices A and B, was it deemed appropriate.

The original purpose of the survey effort was to solicit opinions of key experts in various job categories to assist in the Academy's analysis. It was not intended as a poll of the community nor as a survey in the technical sense of a comprehensive characterization of the beliefs of the entire community of environmental engineers.

This caveat is reflected in every aspect of the survey. Specifically, the survey instrument was a relatively informal tool containing only eight questions. Six of the eight questions were in an open-ended, narrative-response format and consequently the results were not readily susceptible to quantitative analysis. Likewise the sample selection was purposely not statistically representative. Names of prospective respondents were chosen on the basis of their perspective and likely sensitivity to the issues rather than as components in some idealized stratification of the field. In effect, the target population was composed of individuals of more than average influence within the profession and, presumably of more than average insight into human resources conditions in the field.

Procedure

The survey instrument was constructed in June 1979, in a format that provided much explanatory material for prospective respondents. One hundred forty-seven

forms were mailed during the third week of June. The forms included a cover letter, an outline of the prospective position paper, a return postcard to indicate a willingness to complete the form, and a return-addressed envelope for the transmission of the completed questionnaire.

Results and Implications

Of the 147 forms sent, seven were returned as mis-addressed leaving a net contact lot of 140. Forty-one forms were completed by respondents, of which 39 could be scored. Thus, the net response rate was less than 30%. The expected response rate for surveys of this general type is 40%-50%. Therefore, any quantitative analysis and interpretation is necessarily limited -- not just on the basis of the modest response rate and the low absolute sample size but also by the relatively informal structure of the questionnaire. However, respondents' assessments of the main areas of potential long-range shortages of adequate personnel could be given a rough quantitative analysis and the outcome is sufficiently provocative to report.

For example, respondents who were managers of consulting organizations appear to have the most intense concern about personnel shortages -- and, perhaps surprisingly, this concern is focused on the lower levels of formal training (AE/AA, BET). Also, somewhat surprisingly, managers in local government agencies give the impression of having the most moderate expectations about potential shortages. Not surprisingly, the representatives of the educational community show their main concern for shortages at the Master's degree and Ph.D. level, indicating a high concern for the research function. However, they are joined in their concerns by high officials in state agencies. The concerns of equipment manufacturers were, contrastingly, concentrated on the low end of the educational scale.

There are few surprises in the composite picture, reflected in Table VII. Rather, the pattern confirms the expectations generated from the Middlebrooks studies and the NAS report. Specifically, there is a slight emphasis on the

Table VII
Relative Frequency of Indications from all Respondents of Probable Long-range Shortages of Adequate Personnel

Functional Specialty	Education Levels					
	AS/AA	BET	BA/BS	MS/MA/ME	Ph.D.	Totals
Planning	0	1	3	8	3	15
Design	2	2	6	9	3	22
Construction	1	1	4	1	0	7
Operation	16	15	16	12	3	62
Regulation	3	3	8	9	4	27
Research	2	2	5	9	11	29
Education and Training	4	5	4	4	6	23
Totals	28	29	46	52	30	185

Master's degree as the level of greatest potential difficulty (52 out of 185 total mentions of possible long-range shortages). Most clear, however, is the concern for potential shortages in the O & M area. This focus is apparent in the responses from all sources and is almost the sole preoccupation of those respondents from local government agencies.

It is significant, however, that the survey indicated a relatively high concern for the research function. Twenty-nine of the 185 mentions of possible shortages were tied to that function and, with the understandable exception of agencies of local government, the concern appears to permeate the total community of respondents.

The qualitative information obtained from the open-ended items must, of course, be interpreted in an even more impressionistic manner. For example, it should be stated that a small but articulate sub-set of respondents took the opportunity to express the view that the federal government should have no role whatsoever in post-secondary education. (Mainly, industry sources so express themselves.) Others remark that subsidies of students and research is perfectly acceptable but "interference" is not.

Most respondents maintained that much of what is regarded as deficient performance in the field should not be laid at the door of the educators but rather is due to attributes of the individual.

There is a common thread concerning the need for more "hands-on" exposure of students to practical applications - but also some strong and not necessarily contradictory emphasis on such matters as basic science, communication skills and, most particularly, knowledge of the social and legal context in which water pollution control takes place.

The most common response, however, can best be summarized as a concern for the management of incentives. This concern includes the management of the tangible incentives such as those related to a general motivation for environmental improvement (usually associated with pleas for better public

information programs and better materials for vocational guidance at the high school level). At the tangible level, the greatest emphasis is on the factor of competition from other vocational fields. The erosion of the human resources pool is asserted to begin at the early stages of the educational process. A crucial breakpoint comes when a potential Master's degree student is lured away from continued studies by the immediate rewards of alternative work situations.

In general, the concepts of stipend-type support for students at the Master's degree level, subsidy for the upgrading of faculty, laboratory and instructional materials resources, and, most emphatically, support for research within the framework of the instructional programs appear to have widespread endorsement by the leadership element in the field, insofar as that element expressed itself by means of the survey here described.

The best insights with respect to a direction of action come at the intersection between the need for a balance of "practical hands-on" experience and "conceptual and contextual" learning. The emergent recommendations rest in part on the perception that the laboratory capabilities of the training institutions have deteriorated or have become out-of-date with respect to the equipment resources in actual use in the field. Insofar as the laboratory provides one of the major tools for imparting operationally-oriented skills, a high priority should be given to an increased allocation of federal support funds for the modernization of these facilities. A valuable by-product of such an increased allocation would be the improvement of the research capabilities of the institutions as well.

A second tactic directed toward the same general problem would be the increased employment of practitioners in the role of adjunct instructors. Such a tactic could have two valuable consequences if managed properly. First, the students would almost inevitably receive a "real-world" orientation from these adjunct instructors that would be conveyed in the form of actual case studies. Second, the practitioners would become more sensitized to the specific problems

in the process of education and training and therefore, more effective advocates for progressive action in the educational process in their roles as constituents of the professional community.

This second tactic also should involve a consideration of the economics of the situation. For example, honoraria for adjunct instructors are notoriously low in many institutions and academic departments often have no way to adjust the rates to fit current conditions. Special funding for such arrangements should be sought from federal as well as from other sources.

Constraints on Surveys

A comprehensive survey of the human resources supply and demand picture would involve populations of approximately three hundred institutions on the supply side and upwards of three thousand organizations on the demand side.

At least eight different survey forms would be required to cover the variations in the type of organization.

In order to be reasonably current, the survey would have to be repeated on an annual basis.

In order to provide minimal levels of accuracy, a standard nomenclature for positions would be required. This standard would have to be agreed upon by the majority of the employer organizations.

An annual cost of no less than $200,000 would be required for data collection and tabulation. Total costs could reach $500,000 per year for data generation and processing.

The quality of the data collected at this cost, given optimum survey instruments, sampling procedures and return rates and minimal tabulation errors would still be problematic. When efforts of this sort have been undertaken

under the most rigorous survey management procedures, the results indicated "so much variation from employer to employer in what they defined as a 'vacancy' that the data obtained were not just unreliable but could be down-right misleading."

From this it should be clear that the comprehensive survey is probably not the appropriate solution to the problem of providing a factual base for deliberations on human resources policy in the water pollution control area.

The investment in any study effort should be commensurate with the expected value of the outcome. The alternative is to gear investment strictly to the anticipated social consequences.

The problems associated with the second alternative are illuminated by such programs as the "War on Cancer". The potential social consequences of the research on causes and cures for cancer are enormous. This factor was used to justify major expenditures when it was widely realized that the state-of-the-art, the concepts, knowledge base and research tools were not adequate to support a "solution" of the problem.

The tools available for human resource requirements projections are also quite limited. As we have seen, major studies in the past have revealed that projections in the overall area of engineering manpower have been particularly imprecise.

It is not the function of a professional association such as AAEE to invent better methods of human resources requirements projection. We must go ahead with what is provided to us by human resources economists and others that are specialists in this research area.

Thus, while the manpower situation in the water pollution control field may be of great social consequence, our approach is to gear our own efforts and to recommend that the government agencies with programs and related responsibilities in this matter gear their efforts to the realities of what can be accomplished given the methodologies available.

Recommended Strategy

It is recommended that a monitoring function be performed under the auspices of the Environmental Protection Agency. It does not necessarily need to be a unit within government but could be operated under EPA funding in the setting of a university or commercial organization.

This human resources monitoring unit would have two main functions: early warning and reporting of acute problems. The early warning activity should be closely tied to the monitoring apparatus already in place. That apparatus is predominantly in the hands of other government agencies; namely, the Bureau of Labor Statistics, the Office of Education, and the National Science Foundation.

A modest supplementary effort should probably be launched toward the development and/or improvement in the use of long-range indicators. In particular, factors such as salary trends and patterns of career progression should be considered as possible harbingers of shifts in the human resources picture. Similarly, and even more importantly, supplementary data should be gathered on the statistics covering the actual enrollments at all levels of the education and training system. Particular concern should be given to the proportionate numbers of entrants into undergraduate programs in environmental, civil and chemical engineering and the actuarial fate of such entrants--attrition rates, for example, and the rate of employer co-option of potential M.S.-level environmental engineering students.

In short, the main activity in support of the "early warning" function should be the systematic analysis of the large-scale statistical data already available with some augmentation in the form of validated indicators of the production and flow of people at the various stages of career progression.

The reportage of acute problems requires a somewhat different mode of data collection and interpretation. Two, or possibly three, main lines of information flow should be established.

The first of these is the relatively cheap and simple process of tabulating the help-wanted listings from a variety of channels such as a sample of metropolitan daily newspapers plus the advertisements in selected professional publications.

There are obvious limitations in the validity of a picture generated exclusively from these sources. For example, the existence of a listing provides no clue as to whether or when it is filled or the actual qualifications of the person who eventually fills it. If such information is used to the exclusion of other sources, a distorted picture could emerge. Consequently, it is suggested that the "want-ad" source be supplemented by a panel of employers.

In a sense, such a panel would resemble the group of selected employers surveyed in this study. The panel would be comprised of individuals in positions requiring relatively broad perceptions of employment conditions on at least a regional if not national level.

The advantages of a panel would be twofold. First, the panel members would become incorporated into the process so that they would be increasingly sensitive to the human resources environment and responsive to queries. Second, trends over time would be more indicative in the sense of not being subjected to variation due to the introduction of different perspectives. To use an analogy, the errors of estimate would be constant errors, not variable errors, and constant errors are susceptible to systematic correction while variable errors are not.

Finally, some spot surveys could be mounted on an ad hoc basis. The main idea in this regard would be to avoid massive and expensive national surveys while still being able to fill in any gaps in the overall picture produced by help-wanted tabulations and panel responses.

The very process of sharing such information could contribute to the formation of a more coherent community among the organizations involved in water pollution control. The long range effect could be constructive in the sense that

"problems" that could require federal intervention would be recognized simultaneously by all the interested participants and the resultant messages to policy-makers would have a composite impact.

In summary, what is recommended is an information system. Careful cost control would be imposed on the inputs to such a system. Most inputs would be data generated in the normal course of activity by government agencies. More specialized data would be collected by low-cost methods. Processing the data would be predominantly of a routine sort. A modest institutional apparatus would be needed for rush routine activities and the small, residual special studies. The output of the system would be made available not only to federal officials but to the community at large so that decisions affecting the human resources picture could be based on established facts rather than intuition or wishful thinking.

Chapter 6
How Can the Performance of Water Quality Control Personnel be Improved?

To improve the performance of water quality control personnel, we must attract personnel with ability and potential. We must have defined education/training/experience/performance criteria, regarding education, training, and experience. We must have a system for demonstrating ability and performance through certification or accreditation. Furthermore, high quality personnel must be encouraged to remain in the field by providing suitable rewards and incentives such as adequate financial compensation, recognition and prestige, security, sense of public service, opportunity to advance, and a good working climate.

Most practitioners in the field would agree that education and training are critical to the improvement of performance of personnel. However, there is considerable difference of opinion as to what an effective and/or necessary education/training program should be. Does the administrator of a major federal or state program have to be an engineer? A professional engineer? Should a doctorate be a prerequisite for a professor? For teaching of design? What should be the education and experience requirements for an attorney in the environmental field, for an environmental toxicologist, a design engineer, a mathematical modeler, a laboratory director, a plant operator, environmental sampler, developer of rules and regulations? These and other questions remain unanswered.

Are we making effective use of available personnel? Do the stated qualifications for a position match the required qualifications to perform the job? Are we encouraging qualified people to enter the field or are we excluding them by requiring unnecessary education/training? What is the relationship between salaries and ability to attract qualified people? What are the institutional problems relating, for example, to Civil Service or union requirements or political factors, associated with attracting and keeping qualified personnel?

One would expect to have difficulty in attracting, developing, or retaining qualified personnel if the rewards are not commensurate with educational, training, internship, experience, responsibility, and certification requirements.

Qualifications for Position

The qualifications for a job category are best established by individuals who have demonstrated the capability to judge what the position requires with regard to education and experience, and who are also capable of evaluating the performance of the position holder. An example illustrates the point.

A design engineer is a specialist who is called upon to certify that a facility or structure is safe as to structure and operation and that design is based on accepted practice or engineering principles. The design engineer, in addition to an appropriate formal college education, should meet specific course requirements, should have completed an "internship", should have passed written and oral exams prepared, at least in part, by competent design engineers; be certified in specialized areas such as concrete structures, steel structures, foundations, or boilers by competent design engineers; be required to attend seminars, workshops, courses; and be recertified on a periodic basis. The similarity of the above to the medical profession should be apparent.

How and who would establish the qualifications and certify the administrator, environmental lawyer, educators, researchers, plant operators, planners, chemists, technicians, draftsmen? Is certification or licensing necessary? Is ability to perform the only prerequisite or are there education and certification requirements?

Attracting Qualified Personnel

Professional and technical organizations and individuals should make a strong effort to present the challenges and opportunities in the water quality control field to high school and college students and to the general public.

Those in the field should make an objective analysis of whether indeed the opportunities, salaries, advancement potential and personal satisfaction are commensurate with qualifications required or needed. It would be desirable to be as specific as possible in presenting numbers of chemists, designers, lawyers, plant operators, mechanics, etc., needed now and in the future.

Education, Training and Advancement

An over-educated individual in a dead-end position can be as serious a problem as an under-educated or trained individual. Educational and training requirements should relate directly to position and career requirements. Two and four year college programs and graduate programs are frequently necessary prerequisites; however, short courses or on-the-job training and internships may be appropriate approaches. Wherever possible, personnel should be organized along "career ladders," so that each employee can see a pathway of potential advancement within the organization.

Incentives and Disincentives

A number of incentives have been mentioned as ways of improving the performance of personnel. Financial rewards are important but other incentives can be equally important. An analysis should be made as to the trade-offs between financial and non-financial rewards that qualified people are willing to accept. To obtain the numbers of qualified people needed in the field, performance and quality must be rewarded.

One approach is to penalize poor or faulty performance. If penalties were assessed against operators of poorly operated plants and preparers of inefficient and ineffective programs and plans, the value of qualified personnel could be more readily rewarded.

Again, although cost should be the overriding consideration, rewards should be made when there is economy and cost savings and when waste is reduced. The new executive service of the federal civil service attempts to take these

factors into account. Although there are shortcomings in this new system, it does have considerable merit and it should be reviewed for possible application to other governmental programs.

Certification and Licensing

Certification and licensing have a very important role in motivating and improving the performance of water quality personnel if the following three conditions are met:

1. There are specific explicit requirements necessary to perform the function for which a certificate or license is awarded and the certificate or license attests to the competence of the individual.
2. Unqualified people are prevented from occupying a position for which certification or licensing is considered necessary.
3. There are suitable rewards for the certified or licensed individual.

In summary, improvement in performance of personnel can be accomplished by rewarding the qualified and penalizing the unqualified. Rewards may be both monetary and non-monetary. Qualified management personnel should address organizational staffing requirements, in terms of functions performed, of consulting firms, educational and industrial organizations, and treatment plants. This analysis may demonstrate that our manpower needs are quite different than what might otherwise be expected.

Chapter 7
Existing Systems of Training

Existing Systems

A variety of existing systems provides educational and training in the area of environmental protection. These are briefly described below.

Conventional Education

The traditional approach to most education and training in the water quality control field is through full-time programs conducted by institutions whose major emphasis is on instruction. Spread throughout the nation are a number of well-established, well-directed programs at all levels (2-year technician, 4-year technologist, 4-year B.S., M.S., and Ph.D.). Programs are most frequently focused on the M.S. level, closely followed by Ph.D. programs. Next in frequency are the 2-year technician programs. Very few 4-year technologist and 4-year B.S. programs exist. As public and governmental interest in water quality control increased during the late sixties and early seventies, there was a significant increase in the number of programs at the M.S. and 2-year technician levels. The number of programs is now decreasing, however.

Those programs that receive strong support from the institution or from the state usually survive the withdrawal of federal funds.

These programs usually have well established curricula which have been developed over a period of years by experienced instructional staff. In most cases, curricula and courses must go through evaluation at several levels of review as, for example, at the department, college, and institutional levels as well as at the state review board level. In addition, if the program or institution desires accreditation, it must meet the criteria of the accrediting organization. As a result of these constraints, these formal programs are required to make

long-term preparations and plans for changes in courses and curricula. Thus, their ability to adapt programs quickly to immediate specialized needs is constrained.

Some immediate adaptation can be achieved by insertion of small amounts of material into existing courses, using special-topic courses, allowing students to obtain specialized training/education through special problem or thesis work, or conducting workshops, seminars or short courses outside the formal instructional program.

Some institutions allow a student to pursue a course of study while engaged in full- or part-time employment. This extends the period of study over a longer period of time. Part-time programs tend to be available in metropolitan areas where there are usually larger numbers of practitioners who are employed, but also wish to continue their education. Because of the larger number of interested parties, the institution is more willing to schedule classes at times suitable to the part-time student, i.e., late afternoon or evening. The above discussion of strengths and weaknesses of full-time programs applies equally to part-time programs.

Extension Training

Many institutions, particularly state-funded ones, have some type of extension program. These programs may offer courses of study similar to those available to full-time students and with similar credit, or they may offer programs giving credits in Continuing Education Units (CEU). The type of course work offered can be more varied than that of conventional institutional programs as there are fewer constraints on course content and coverage. Thus, the program can be more flexible and is able to respond more quickly to changing needs. Considerable leeway is available to the institution in its application of CEU's to instructional programs. One big advantage of these programs is that the institution can conduct the program at a time and place convenient to the students. In addition, the institution can work with licensing and certification boards in designing courses to meet CEU requirements for particular licenses or certificates.

A number of the professional organizations in or associated with the water quality control field are involved in extension training. Often this training is performed in conjunction with an institution, with the professional organization supplying the instructional personnel. In most cases, a professional organization cannot give credit for courses; alliance with an institution solves this problem. Professional organizations usually have excellent access to potential trainees. This simplifies marketing of the programs.

Short-term Education/Training

Because all of the above systems are in some degree constrained in their ability to quickly adapt to changing educational/training needs in the water quality control field, it is often advisable to have these and other organizations sponsor workshops, seminars, professional meetings and other types of technology-transfer activities to keep the profession abreast of the latest and best information. Consulting firms and federal and state agencies, as well as instructional institutions and professional organizations, make use of these delivery mechanisms. These types of programs are widely used throughout the country. In some of these, CEU's may be offered. There is little control of the quality of content or delivery. This is essentially left up to the developers of the program and the sponsoring organization. Thus, the educational/training experience is likely to be less well developed and perfected than that provided by the systems discussed previously. However, training is more likely to be related to their current needs on the job.

Correspondence Courses

Correspondence courses in the water quality field are scarce. They are available only in several specialized areas in the water quality field, usually in such practical areas as management and operations and maintenance. Both institutional credits and CEU's are available in these programs. Some are administered by institutions and some by professional organizations. Most are set up so they can be used in either a correspondence course format or a more formal instructional situation. The major use of these programs is in the upgrading of operation personnel in water quality control systems. Quality control is maintained by the system that authorizes credits and CEU's.

There is no way to directly measure the cost-effectiveness of any of the systems described above.

Manpower Needs

Education institutions are not organized to respond quickly to immediate manpower needs. The mechanisms used to establish new courses and curricula, with approvals at the department, college, university and state board of education levels, require several years of lead time. Two-year degree programs have a somewhat easier time in establishing new programs, than do 4-year programs, as many of these are mandated to respond to the needs of the area they serve. Thus, if the local need matches a national need, the response time can be short. However, many 2-year programs have been established to serve specific geographical areas, and they find it extremely difficult to initiate programs aimed at serving needs which serve a wider area.

The best way the educational/training community can meet immediate manpower needs is to establish and implement a variety of short-term training programs in specific areas for current practitioners in the profession. These persons can usually assimilate the new knowledge and skill in minimum time and put it to use quickly, thus meeting the immediate need.

Lead Time in Implementing Programs

As stated above, 4-year educational institutions have the longest lead time requirements in responding to manpower needs. Two-year institutions usually can respond somewhat more quickly, and short-term specialized training programs have the shortest lead time requirements, though inevitably the training provided by these mechanisms is correspondingly less comprehensive. The traditional mechaism for shortening lead time is to provide funds for a specific program rather than waiting for the system to respond. This was done by EPA in the late sixties and early seventies to retrain aerospace technical personnel for careers in the environmental field. Funds were made available so that educational and training organizations were able to respond quickly.

A number of alternatives have been used in recent years. EPA and other governmental agencies with environmental programs have funded educational, training, consulting and professional organizations to develop and implement short-term programs to increase the supply of manpower in specific areas. In addition, EPA instituted a Technology Transfer program to carry out the same type of endeavor. All of these efforts shorten the lead time in providing qualified manpower.

Funding and Availability of Funds

The numbers of institutions and organizations involved in educational/training activities is directly related to the amount of federal funding. Prior to the increased interest in the environment by the public and Congress in the mid-sixties, a number of institutions, both private and public, had established strong water quality programs. With the advent of environmental awareness, the number soon doubled. During this period, EPA was sponsoring over 100 programs in water quality control.

These funds had several effects on the delivery system. They strengthened existing programs so they could increase the number of graduates. They allowed small programs to increase the size of their staffs, numbers of students, and extent of their facilities. They allowed new programs to start. However, they also produced some individuals whose preparation was in fact too shallow to conduct the work required. In addition, they supported some programs that should have been terminated.

It is interesting to note that some of the programs aided by the increased federal inputs were able to develop strong programs which, as the federal funds were withdrawn, were kept viable by increased funding from their own organizations.

Human Resources to Implement Programs

As funds are made available for increased program activity, the human resources soon follow. During the peak of the environmental movement, the salaries for instructors were competitive with other positions in the environment and it was

usually not difficult to find qualified personnel. During the last 5 years or so, instructor salaries have not kept pace with others in the field and thus, there has been some loss of instructional talent.

Responsiveness of Existing Systems to Manpower Needs

The need for water quality control personnel over the last decade has been described earlier as has the response of the educational/training organizations to this need. Increased funding by a variety of governmental programs increased the supply substantially as indicated above. In general, private organizations had the pick of each year's crop of students at the B.S., M.S., and Ph.D. levels, and thus were able to fill the spots they had with the quality and quantity of personnel they needed. Usually they were able to obtain the personnel when needed because they could offer enticements to prospective employees. Public agencies did not fare so well. Often they would leave positions unfilled for periods of time or hire persons with training not specifically oriented for the position. For instance, persons with chemistry or biology backgrounds would be hired for review of plans. Thus, a shortfall would not be evident because a person was filling a position, even though his background and experience might not be entirely adequate for the tasks to be performed. This deficiency was sometimes covered by additional training on the job or through specialized courses.

The ability of 2-year institutions to respond reasonably quickly to certain types of manpower needs helped mitigate manpower shortages. Many of the requirements for jobs were not as specialized at the technical level, so graduates from other disciplines could move into openings in the water quality control field. These included chemical, biological, and engineering technicians.

Some of the suggestions discussed in the following sections outline procedures which would make it easier for existing systems to respond to manpower demands.

Responsiveness of Existing Systems to Funding

During the period of peak interest in the environment, funds were plentiful for program development and implementation at the technician, technologist, B.S. and advanced levels of education/training. However, as additional priorities emerged, the supply of funds diminished. During the last few years, the government's policy has been to supply funds for design and construction but not for the manpower to do the design, operaiton, or maintenance of the facilities. In this way, the funding system is not responsive to the manpower needs. Numerous reports indicate that large numbers of plants do not meet design or NPDES guidelines because of untrained personnel involved in the plant's operations.

Alternatives That Might be Used to Supplement Existing Systems

A number of alternative or innovative systems might be used to help meet the need for skilled manpower. Where some of these systems have been tried elsewhere, it has been found that some aspects of them do have application in the more traditional methodologies and often can be used to improve the traditional delivery system. Although there are many variations that might be tried, only four will be discussed here: self-paced study, correspondence courses, open university and centers of competence.

Self-Paced Study Systems

Self-paced materials are materials that have been developed and field-tested so that trainees at the selected level of competence in the subject area can use the materials on an individual basis. After completion of the materials, a high percentage of the students will have accomplished the performance objectives. All types of media can be used--printed materials, slides, audio tapes, slide/tapes, videotapes, overhead transparencies or motion pictures. Many different formats are possible. The essential features of a self-paced module are reflected in the following questions:

- What is This Module About? A statement of the overall content of the module.

- Why Do I Need to Learn This? The reasons the material is important to the trainee and where it will fit into his/her knowledge and skill requirements.

- What Do I Need to Know Before I Begin? A list of the knowledge and skills the trainee must have before beginning this new material. Often this is a list of prerequisite modules.

- What Equipment and Supplies Do I Need? A list of materials needed to carry out the instruction. These are often listed by objective.

- What Supplementary Materials Will Help Me? A listing of additional resource material which will offer different media and approaches to the instruction or go beyond what is in the module.

- What Are My Objectives? A listing of the objectives the trainee should have achieved upon completion of the module.

Following the introductory material, the detailed instructional material is presented unit by unit. The units of instruction are of appropriate length and content. Each unit is composed of:

Action - A statement of the performance required by the trainee after completion of the material. Only action verbs are acceptable in these statements.

Conditions - A statement of the conditions under which the trainee will perform this action in practice. This would include what aids the trainee would or would not have (e.g., a reference, a calculator) or under what environmental conditions (e.g., working under 3 feet of water).

Performance - A statement of the quality of performance, such as percent correct or a restricted tolerance, or conformance with a particular guide.

Instructional Material - This may take many forms, including text, pictures, exercises, slides, tapes, and other types of media.

Diagnostic Test - In order for the self-paced material to be complete, it is necessary to build trainee self-assessment into the instruction. An evaluation instrument and answer sheet should be included with each module. After meeting all the objectives of a module, the trainee can complete the test to determine if he/she has mastered the material.

Often a series of modules can be combined in a unit of instruction. Trainees may have some of the knowledge and skills required, yet be missing others. To minimize repetition of material already in the trainee's repertoire, a comprehensive diagnostic test can be developed which will determine what level of competence he/she has attained and, thus, which modules may be omitted and which should be studied.

A diagnostic test is often accompanied by a test "prescription." The prescription lists which module and objective relates to each test item. Thus, if a trainee does not meet an objective, he/she can ascertain where the material is and go back and correct this deficiency in knowledge or skill.

Basing an instructional program on the development of self-paced materials adds a great deal of flexibility and economy of time for both trainees and instructors.

A person administering the instructor-assisted-self-paced mode does not serve in the usual instructor role, but rather as a manager of the instructional process. The same instructional materials are used as discussed above. Whereas the trainee working alone must repeat units of instruction one or more times or seek help when it becomes available on a particularly difficult point, the trainee working on these materials in the presence of an instructor can get almost immediate assistance. An advantage this has over traditional instructor methods, where the same material is to be presented by a number of instructors at the same or different locations, is that subject matter is presented consistently and in a uniform format. This helps to ensure that program graduates will exhibit "mastery" level performance of the knowledge and skills, rather than the usual bell-shaped curve distribution of performance.

In programs of this type, an information transfer method is used which is economically and methodologically most efficient for the instruction intended, and which makes the instructor's role one of managing the instructional process by clarifying motivating, encouraging, and assisting the trainee to extend himself to other training materials. A trainee who learns quickly can complete more materials over a set time period because he is not in a lock-step program set by the instructor (or the slower student). On the other hand, the slower student can take additional time to study material and not hold up the class. The shy student can interact one-on-one with the instructor and receive assistance immediately and to the depth required, whereas in the normal class he/she may not seek assistance because of fear of appearing to be slow to learn. From an economic standpoint, trainees may be working on different modules at different times, thus eliminating the necessity of having complete set-ups of equipment for each trainee. Use of the diagnostic tests and prescription described above will assist in organizing an instructional effort in this way. A trainee who masters the required objectives and modules can either go on to more advanced material or make use of supplementary materials to strengthen grasp of the material or extend knowledge and skills.

The instructor-assisted-self-paced method is used when:

1. Groups of trainees in one location need similar instruction, supplies and equipment.
2. The instruction can be given at only one location.
3. Trainees need an instructor because of deficiencies in prerequisites, lack of self-confidence (need constant reinforcement), lack of motivation (need frequent praise), and lack of good study habits.

The trainee who moves quickly through the instructional sequence may serve as a peer instructor, helping those who need assistance. The trainee acting as a peer instructor gains by reinforcing his/her knowledge and skill by having to work with someone else. He/she has the advantage over the instructor of having just gone through the learning process and can often diagnose another trainee's problem faster. Also, the trainee who needs help does not feel as "threatened" by a peer instructor, and a better line of communication is established.

Correspondence Course Systems

Correspondence course systems are not new to the water quality control field. Back in the 30's the Scranton Publishing Company published a correspondence course for persons in the water quality control field. This course was for relatively advanced study. Several states have initiated correspondence courses for operator training programs. South Carolina has had eight courses in use since the early fifties. Three correspondence courses have been developed in the last few years; one for the operations and maintenance of wastewater treatment plants (Kerri, 1979), a second for operation and maintenance of wastewater collection systems (Kerri, 1976) and a third for supervisory and management aspects in the water quality control field (Michigan State University, 1976). One aspect of the correspondence course system is that it offers either CEU's or academic credit. This, along with the flexibility, is a great inducement to many persons. The advantages described above for the self-paced study system can be incorporated into correspondence systems, which can be administered in a similar fashion.

Many institutions of higher education have extension programs which make use of correspondence programs. The water quality control field might consider making greater use of these extension programs and adapting more programs to delivery by correspondence mechanisms.

Open University Systems

The open university concept, in which students work independently with training materials with only intermittent monitoring, has a great deal of success in England and has made some small headway in the U.S. This type of program caters to those individuals who cannot afford (either time or funds) to attend a full-time program at an institution, yet who want to advance up their career ladder. The self-paced study materials and correspondence course materials discussed above could be used in this system. Serious consideration should be given to the use of the open university concept in supplying needed instruction to practitioners in the water quality field.

Center of Competence

Over the last few decades the concept of Centers of Competence or Centers of Excellence has been discussed by members of the academic community and various government agencies. A few of these have been established in some fields. There has been some resistance to this in the water quality control field because some felt that the limited funds available would be designated to one or several centers, with the remaining institutions being left out. The rationale involved was that since the needs for personnel in the field are dispersed throughout the country, the opportunities for education/training should be dispersed. However, EPA recently initiated a center of research on pollution control technology at the University of Illinois. The major purpose for a center of excellence is to provide quality standards. This can be accomplished by some of the mechanisms suggested in subsequent sections.

What Role Might Employer Groups Play in Improving the System in Use?

With the rapid advance in technology available to the practitioners in the water quality control field, the frequent changes in laws and regulations relating to water quality and the increased emphasis on public participation, it appears that the employers of water quality control personnel will have to become more involved in maintaining the quality of their personnel. This means that they should play a bigger role in continuing education programs. It would behoove employers of water quality control personnel to make available the best in self-study materials for their employees, and to cooperate with groups sponsoring continuation programs.

Many employers over the last few years have increased employee benefits in relation to the upgrading of their knowledge and skills. These benefits might include direct payment of tuition or tuition reimbursement, or sponsoring programs in-house, at no cost to the employer. Several ideas might be implemented to promote more involvement between employers and institutions or organizations who supply instruction. These include:

- Increased awareness and knowledge of education/training programs by employers and employees.
- Motivation of employees at all levels (national, state, local) to participate in continuing education programs.

- Offering of continuing education programs on-site at a variety of times, such as at lunch hours; before opening, after closing hours, or at the end of shifts; during seasonal or layoff periods; or on weekends.
- Organization by employers to encourage continuing education organizations to provide programs, formal and self-study, for their employees.
- Designation by employers of selected employees to work with educational/training organizations to assist with program planning, course development and scheduling.

A major function that employers could perform is the establishment of performance criteria for their employees. These criteria would define the knowledge and skills required by the employee in their day-to-day tasks. Several projects have already been undertaken to define performance criteria. Practitioners in the field worked closely with curriculum developers and eventually devised programs which were built on performance criteria. These could serve as models for other such efforts in the water quality control field. They include EPA sponsored projects for wastewater treatment plant operation training (Environmental Protection Agency 1973, 1975, 1976 a, b, c); water quality monitoring technicians (Ulster County Community College, 1975, 1978, 1979 a, b); bachelor of engineering technology curriculum in wastewater design and operation (Clemson University, 1974, Clemson University and University of Maryland, 1978) and a bachelor or engineering technology curriculum in water quality management (Pennsylvania State University, 1979 a, b).

Evaluation of existing and planned education/training programs should be carried out by practitioners. Some accrediting procedures such as those by the Accreditation Board for Engineering and Technology (ABET) do include practitioners. This practice should be more widely adopted to ensure the relevancy of programs. The use of performance criteria greatly assists in evaluation of employees.

An additional way for employers to become involved with both full-time study programs and continuing education programs is to be involved with on-the-job training during the program. The programs described above all include this type of experience. Greater application of this type of experience will enhance the relevancy of the education/training program and help eliminate some of the extensive "retraining" or "orientation" programs used by some employers.

What Role Should Education/Training Institutions Play in Improving the System in Use?

In the previous section the importance of employers interacting with institutions and organizations concerned with the education/training aspects of the water quality control field was stressed. It is equally important for the education/training community to interact with employers to be sure they can respond effectively with their needs. If routine interactions are implemented, it will be possible for these institutions and organizations to anticipate the quantity and quality needs of the profession and plan programs so that the proper numbers of personnel with adequate knowledge and skill are available at the right place at the right time. If some of the alternative delivery systems discussed above are instituted, it would be easier to implement materials to supply immediate manpower needs since appropriate instructional materials would be ready to use in a short-term upgrade program.

Educational and training institutions have traditionally used very highly trained personnel as instructors. The more advanced the program the greater the insistance on personnel with advanced degrees. In many cases this has been accomplished by use of persons with little or no practical experience. A second major emphasis is on instructors with ability to obtain research funds and produce technical papers. The ability of an institution to accomplish these goals is usually equated with success. The technician programs, on the other hand, tend to hire instructors with practical experience in the subject matter area. In either case, the ability of the instructor to manage the instructional process, which includes transferring information, using instructional media effectively, motivating and encouraging trainees, troubleshooting the learning process, developing new instructional sequences, etc., is not given high priority. Educational and training institutions should give more attention to the abilities of their instructors to manage the instructional process, and insist on improvement where individuals are found lacking. Many programs are available from institutions, professional organizations, and commercial organizations to assist with this effort. The efforts an insti-

tution is making toward improving the quality of its instructional effort should be considered in an evaluation of whether it should be funded to carry out publicly sponsored programs.

The efforts institutions make toward implementing items discussed above will greatly enhance the relevance of the instruction they provide. Cooperative efforts between these two groups should make communicating with governmental organizations more effective and help ensure educational/training programs that are more meaningful in meeting water quality manpower needs.

Some specific activities that educational and training institutions might perform are:

- Establish or cooperate with existing programs aimed at improving the instructional capabilities of personnel engaged in information transfer.
- Establish liaison with employers and investigate and implement alternative delivery systems for teaching employees.
- Cooperate with employers in establishing performance criteria which reflect on-the-job performance, and utilize these performance criteria in the development, implementation and evaluation of instructional programs.
- Investigate with employers the possibility of broadening continuing education programs on-site or through self-study programs.
- Establish media-based instructional centers at various locations for use by employers.
- Develop mechanisms for alternative ways to obtain continuing education units and degree credits through alternative programs.

In What Ways Can Employers and Education/Training Institutions Integrate Their Activities?

A number of efforts could be made relating to determining manpower needs. These include:

- Establishing uniform methodology of job descriptions so that personnel will all be counted the same way.
- Establish procedures for employers for updating manpower needs and conveying these to educational institutions.
- Establish procedures for updating and generating new job descriptions.
- Establish procedures for evaluating program graduates at various times after completion of programs to determine if program has prepared them for positions they hold.
- Establish procedures for alerting the federal government to manpower needs.

Efforts could also be made relating to establishing policy for education/training programs. These include:

- Establish joint committees to determine performance objectives for programs.
- Establish joint committees to set up evaluation procedures for programs.
- Establish joint committees to establish types, levels and locations of programs.
- Establish joint committees to advise local, state and federal agencies on education/training policy.

It is appropriate that efforts be undertaken relating to providing input to state and federal agencies and Congress. Appropriate activities include:

- Establish joint committees to draft policy, legislation and funding proposals.
- Provide updated information on program successes and shortcomings.
- Invite agency personnel and members of Congress to visit or take part in activities and programs.

It is highly desirable that performance criteria be established for program graduates. This would involve a number of activities, as follows:

- Establish procedures for documenting performance objectives for all levels of water quality control personnel.
- Establish procedures for review of performance objectives by employers, employees, instructors, and trainees.
- Establish system for storing and retrieving performance objectives.
- Establish system for evaluating program materials, curricula, courses and program graduates based on performance criteria.

A number of steps are necessary to ensure that program content is appropriate and that instruction is effective. These include:

- Establish procedures for development of instructional materials, types of media and delivery systems.
- Develop and implement training-of-trainers programs.
- Develop procedures for input of new program content.
- Develop procedures for evaluation of programs, materials, instructors and trainees.

It would also be helpful for there to be some sharing of personnel between employing organizations and educational institutions. For example, it would be helpful for employers to be involved with such things as: establishing performance objectives, developing instructional materials and programs, instructing in programs, evaluating programs, arranging on-the-job training of trainees, and arranging for on-the-job work experience for professors and instructors during sabbaticals, leaves or vacations.

Similarly, it would be constructive for instructional personnel to be involved with placing trainees in on-the-job work assignments, performing actual work assignments with employers during their sabbaticals, or vacations, and evaluation of employees who have been through instructional programs and are now on the job.

How Should Criteria be Established for Evaluating the Quality of Programs?

In the earlier sections it was suggested that a systematic approach be established to define performance of program graduates. A number of efforts have been implemented in the water quality control field and could serve as a basis. These include Reynolds and Austin (1972), Lukco, Bela and Austin (1973), Association of Boards of Certification (1976), Charles County Community College (1974), and Environmental Protection Agency (1977). All of these stress the concept of defining the performance of the program graduate. Once this is accomplished a basis is established for the design of an evaluation system. Just such a system has been established for the certification of water and wastewater operators (Association of Boards of Certification, 1977). However, very little evaluation of institutional programs is done on the basis of the performance of program graduates. Evaluation of technician, technologist and engineering programs is conducted by the Accreditation Board for Engineering and Technology (ABET).

ABET has established criteria relating to numbers and quality of staff, physical facilities, and course content, both technical and nontechnical. Little attention is given to the performance of the program graduate once on the job. It appears that the evaluation could be strengthened by more extensive evalua-

tion of program graduates. This not only would evaluate program quality but it would provide a continuous update of the relevancy of the content of programs.

It is suggested that all of our evaluation systems be reviewed for their relevancy and effectiveness in measuring performance of graudates. This would include certification systems for operators, licensing systems for engineers, accrediting systems for academic programs for technicians, technologists, B.S. and M.S. graduates, and systems awarding CEU's. There are existing mechanisms for carrying out these evaluations which can and should continue to perform these functions. What is needed is a reappraisal of the evaluation procedures and methods to determine just what the present systems are and are not telling us about the programs or personnel being evaluated.

Chapter 8
The EPA Role in the Improvement of Training Programs and Personnel Preparation

We live in a paradoxical age. Our scientific and technological expertise now permit us to accurately measure pollutant concentrations in parts per trillion. Yet the chief thing that these technological advances has led us to discover is how much more there is to discover. Former Environmental Protection Agency (EPA) Administrator, Russell Train, (framer of many of today's major regulations) summarized the inadequacy of our scientific knowledge concerning natural systems and their interactions with pollutants: "What we do not know still far exceeds what we do know." When does a pollutant become dangerous? Carcinogenic? Teratogenic? Mutagenic? At what level is it toxic to fish? To man? Will it synergize and with what? Can we eliminate it? What will the trade-offs be? Questions such as these continually plague both administrators and researchers.

Industrial growth has transformed the environment into a virtual Pandora's box filled with questions and uncertainties and, unfortunately, it appears that the contents are overflowing. The uncertainties increase with each Love Canal, with each major spill.

A rising public sensitivity toward public health effects (particularly cancer) forced Congress in the late 1960's and through the 1970's to deal with environmental uncertainties. In the wake of this rapid rise in public awareness Congress drafted sweeping new laws with idealistic goals aimed at improving our nation's air and water. A range of environmental legislation established federal goals. In an attempt to execute these laws and achieve these goals, mountains of regulations grew. Regulation represents society's recognition that its traditional standard of living has created problems. More importantly, it represents society's acceptance of the fact that certain sacrifices are necessary if environmental problems are to be safely resolved.

The execution of this task has not been simple. Environmental regulations are inherently complex. They often intertwine political, economic, social, biological, and aesthetic values, issues and impacts. The professional environmental workforce was faced with an enormous task. They have been forced to assess risks and benefits of intrinsically unquantifiable variables. How many sacks of potatoes are worth how many human cancers? How many cotton bales are worth how many shellfish or the extinction of the peregrine falcon or how much disruption of the ecosystem? The answers cannot be derived from standard equations or programs. Public preference, operating within the limits of scientific necessity, economic efficiency, and political compromise, must dictate the proper calculus. There is a critical need for an adequately educated workforce to provide the guidance for answering these difficult questions. Congress recognized this need and authorized training at virtually all levels in the new environmental legislation.

In 1975, the subcommittee on Graduate Education of the Federal Interagency Committee on Education (FICE) prepared a report which outlined the basic principles for federal support of all graduate education and made recommendations for the future role of the federal government in support of graduate education. The major points are paraphrased below:

- America's graduate education and research establishment is a national resource. Furthermore, America's capacity to respond to changing societal needs, both culturally and technologically, depends upon the maintenance of the talent pool in intellectual, scientific, and human service areas. Much of the necessary knowledge, as well as the expertise to utilize it fruitfully, is in the centers of excellence in the nation's graduate schools.

- The market for highly trained manpower is national. Such manpower is very mobile. Since the benefits of such training are so widely dispersed, neither private nor local and state sources can be expected to assume the entire burden of financing such training.

- The federal government employs the services of highly trained personnel. In cases where such employment involves a high percentage of personnel in a particular area, it is cheaper for the government to finance their training at universities than to train them itself or to wait for market forces to supply them.

- In certain situations, it is in the national interest for the federal government to stimulate response to changing manpower and knowledge needs; for example, if market response were very slow and if the social cost of such a slow adjustment were high, federal intervention would be justifiable. It takes an average lead time of approximately 5 years to produce a doctorate recipient. Federal support may help reduce the lag time in two ways: (1) by facilitating entry into the needed fields, and (2) by reducing the time needed to earn a degree.

- By supplying incentives, the federal government can encourage students to enter careers that, though less lucrative, are in the national interest. Low lifetime incomes associated with careers requiring extensive advanced training may deter students from choosing such careers and may result in manpower shortages unless federal subsidies are provided.

- Federal involvement in areas such as research and development is so dominant that government decisions have a far-reaching impact on both the supply and demand for knowledge and manpower; hence, federal policy may be the major force to contend with. The question is not, "whether or not" but rather "how much" and "in what areas" support is necessary.

- Knowledge, especially basic knowledge, is part of the public domain. Its wide diffusion and consumption is in the national interest. But the benefits associated with such knowledge are non-appropriable so there is no assurance that the developer will profit directly. The high risk and uncertainty involved may result in an insufficient investment for the public's benefit unless there is federal support.

- The federal government can best redress social disadvantages resulting from disparities of race, income, ethnic origin, or sex. It is in the national interest to overcome culturally or financially induced constraints on attending graduate and professional schools so that members of a wide variety of groups are represented in the selective areas of academia and the professions.

The FICE subcommittee on graduate education concluded from these basic principles that the federal government has two primary responsibilities concerning graduate education. First, it has the responsibility to assure availability of sufficient manpower and knowledge to meet specific areas of national need. Second, it has the responsibility to assure that an optimum pool of qualified talent exists in all areas of knowledge essential to the long-term cultural and practical requirements of the nation. The preceding analysis of federal responsibilities led the FICE subcommittee to make the following recommendations:

- The federal government should provide graduate support for advanced academic study to meet national manpower needs essential to the attainment of agency missions. In addition, such unique federal programs as the NIH-ADAMHA training grants, which provide more complete training, research, student support opportunities, should be expanded and encouraged.

- The federal government should provide full financial support for a limited number of highly talented students, selected in national competition, in all academic fields and recognized professions. Such awards should be complemented by a cost of education allowance to the institution a fellow attends.

- The federal government must maintain consistency and stability in levels of support for graduate education. Abrupt changes are wasteful and inefficient.

- The federal government should evaluate the advantages and disadvantages of national service pay-back conditions in return for fellowship or traineeship support. The study should include consideration of fellowships that would follow a period of national service.

- The federal government should strengthen its capability for anticipating emerging manpower needs and should provide grants to strengthen and improve the quality of graduate and professional programs designed to meet such needs.

- The federal government should maintain a balance in its research and scholarship expenditures between targeted, high payoff research and development and less directed pursuits of fundamental scientific and intellectual knowledge.

- The federal government should initiate and implement a variety of measures, in addition to those mentioned above, specifically designed (1) to prepare disadvantaged racial and ethnic minority students for graduate study in all academic and professional fields and (2) to support the post-baccalaureate training of highly qualified disadvantaged racial and ethnic minority students.

The specific question of academic training for the environmental workforce was addressed in a report prepared by the National Academy of Sciences in 1977, as mentioned earlier. It was noted in this report that a shortcoming in the process of the development of environmental legislation was the failure to develop realistic evaluations of manpower requirements for achieving stated goals on schedule. As a result, the report noted "...programs must be initiated to train a supply of manpower to design and build advanced systems where required and to operate and maintain them." This point of view was supported by the National Commission on Water Quality report on the institutional constraints on environmental legislation which stated:

> "An efficient and effective program of operating maintenance is essential to achieving the objectives of the construction program. Without efficient operation and maintenance, many of the dollars spent in construction will be wasted."

The level of government that should assume the responsibility for training environmental manpower is a question concerning which there are diverse opinions. In 1962 the federal government initiated a manpower training program with an appropriation of $800,000. This program increased in size and produced the current nucleus of environmentally trained scientists and engineers. The 1977 National Academy of Sciences report expressed grave concern about the future supply of manpower, however, because of the severe curtailment of these programs by EPA. "It is not realistic," said the Academy, "to assume that training of needed environmental manpower will occur without incentive and financial support instigated by the federal government." The report noted that there is currently no evidence that alternative programs are being developed by the states to fulfill these training needs.

The often suggested concept "the free market is ready to take over" is simply not applicable to the case of the environmental workforce. In order for the free marketplace concept to be effective, salaries must be readily changeable to meet the existing market conditions. While this is the case in private enterprise, the majority (52.4%) of the environmental workforce is employed by various levels of government and/or universities. Table VIII taken from the 1977 NAS report, gives the actual distribution of scientists, engineers, technicians and skilled operators.

The majority of environmental personnel working state and local governments are often underpaid in relation to their educational qualifications and their salaries are not readily adjusted. The National Academy of Sciences recognizes this difficulty with salaries and stated in its 1977 report that "salaries paid to environmental pollution control workers by state and local governments must be made competitive. It is folly," said the report, "to assume that the environmental legislation of recent years will be fulfilled without greater attention to long-range planning which will assure that the necessary environmental manpower is available to perform the tasks necessary to achieve environmental objectives and that salaries are adequate."

The National Academy of Sciences made a series of seven conclusions and recommendations based on their analysis of environmental manpower needs. EPA has yet to respond adequately to the NAS suggestions, which deserve further attention and are quoted below.

CONCLUSION 1

Past training programs supported by EPA have been most helpful in providing trained environmental manpower, but the Panel views with concern the lack of funding and planning for their continuation. It is not realistic to assume that training of needed environmental manpower will occur without incentive and financial support instigated by the federal government.

Table VIII
Estimated Direct Employment in Pollution Control Activites
Summary Data 1974

Occupation	Type of Employer						
	Federal	State	Local Government	Industry	Educational Institution	Other	Total
Scientists	11,400	3,800	2,200	14,900	5,500	3,100	40,900
Engineers	8,300	5,200	5,700	64,700	1,300	8,800	94,000
Technicians	1,000	2,000	20,000	25,000	NA**	NA**	98,000
Skilled Operators	4,000	NA	155,000	112,000	NA**	NA**	271,000

*National Academy of Sciences, Vol.V, Manpower for Environmental Pollution Control

**NA - indicates those areas for which data were not available

RECOMMENDATION 1

The federal government should provide more encouragement for professional people to enter occupations in the environmental field. EPA, especially, should assume leadership for the responsibility in providing the supply of required manpower.

CONCLUSION 2

No consistent view of future environmental manpower needs or policy to assure that future needs are met appears to exist within EPA. Also, no plan emerges for a concerted effort to deal with future environmental manpower shortages.

RECOMMENDATION 2

EPA should develop and implement a policy for manpower development and regular evaluation of its policies in achieving its manpower goals. Specific attention should be given to an analysis of the kinds of specialization required to solve specific environmental problems, and to the development of training programs to ensure a continuing supply of trained personnel for these purposes.

CONCLUSION 3

Elimination of financial support for manpower training is detrimental to achievement of EPA's environmental aims. The cost of poorly designed and operated treatment facilities is greater than is usually anticipated. The Panel recognizes the need for a continuing supply of trained staff to operate and maintain existing future sophisticated waste treatment plants. Evidence indicates that many plants are operating far below expected efficiency and capacity because adequately trained operations personnel is not available.

RECOMMENDATION 3

Immediate steps should be taken to eliminate this defect by providing incentives to ensure that the necessary trained personnel are available. The federal government has a responsibility also to assume leadership in providing incentives and financial support for training and attracting qualified specialists for these positions.

CONCLUSION 4

Congress has recognized the importance of environmental quality and has enacted laws for improving environmental quality. However, it has done this without adequate consideration of the manpower required to achieve desired environmental goals.

RECOMMENDATION 4

Manpower requirements should be considered in drafting legislation on establishment of environmental standards and regulatory procedures and throughout the entire legislative process. This should prompt all agencies charged with administering statutory provisions to be responsive to manpower needs on a continuing basis. A thorough analysis of manpower requirements should be included in debates on proposed environmental legislation by Congress.

CONCLUSION 5

In practice, a disparity exists between legislation authorizing action to protect the environment and subsequent appropriations for financing these activities. Laudable environmental goals in Congressional enactments may not be achieved because of technological difficulties or financial strictures.

RECOMMENDATION 5

EPA should carefully determine the reasons for failure to achieve environmental objectives and identify obstructions to progress, whether they are technical complications, manpower policies, lack of funds, or other deficiencies. EPA should strengthen its communication with Congress concerning the technological and manpower considerations for effecting its environmental pollution programs.

CONCLUSION 6

Manpower activities in EPA are relegated to a low priority.

RECOMMENDATION 6

Program managers with the responsibility for manpower should be at sufficiently high grade levels in the administrative structure of EPA, or a chief administrator should be appointed for planning and evaluating manpower to meet current and future needs.

CONCLUSION 7

Although the Panel has not analyzed the management of EPA in detail, the general view is that delays in reaching decisions may create a morale problem. An observed excessive turnover of individuals in specific job assignments may also affect efficiency adversely. EPA personnel are highly trained and a special effort should be made to use their capabilities and maintain continuity in assignments.

RECOMMENDATION 7

To improve managerial functions, program administrators should be given the maximum authority required to accelerate action on EPA's programs. EPA regulations need to be drafted based on technical realities with the technical input in proper balance. The technical personnel in EPA should make greater input in developing rules and regulations.

It is clear from the basic principles for federal support of graduate education established by the Federal Interagency Committee on Education, from the recommendations and conclusions of the National Academy of Science's Report on Manpower for Environmental Pollution Control and from the conclusions of an array of other supporting material, that the federal government should coordinate and financially support the development of our environmental workforce. It is also clear from the legislation that EPA is the agency that should assume the leadership role.

Appendix A*
The Existing Fact Base for Policy Development on Human Resources for Water Pollution Control

Introduction

What do we know now and how can we come to know better in the future about human resources for water pollution control? The significance of these questions rests on one crucial assumption: if the true facts are known, the best policy will emerge. This basic assumption is central to our present procedures of governance at all levels. More particularly, in circumstances where the issues are controversial, the presence of an unambiguous factual base should help to limit the range of contention. The present situation regarding human resources for water pollution control has its controversial aspects. The facts should not only help resolve some of the controversy but, if used properly, should speed up the entire process of deliberation.

Conceptual Base

The availability of human resources for any given enterprise can be influenced by a wide range of factors. At the base are broad demographic factors that define the reservoir of overall national capabilities. Birth rates, morbidity rates and mortality rates control the stock from which the human resources for any given enterprise can be drawn.

While even these basic demographic factors are increasingly targets for national policy consideration -- and possible governmental intervention -- the more direct controls involve other factors. At the extreme conceptual distance from demographic factors are what might be called employment opportunities. At this level, we are concerned with such specifics as demand for particular categories of individuals, conditions of work, job locations and rates of pay.

Intermediate between demographic and employment factors are the factors of education and training. A graphic model of the relationships between these factors is provided in Figure 1. Relative numbers and sense of the time dynamics are suggested by the diagram. Figure 3 shows, for example, that changing demographic factors to influence the total potential resource requires the greatest planning lead-time, has the least immediacy of impact, and is the least controllable. On the other extreme, changing job market factors to influence numbers of people at work requires the least planning lead-time and has the greatest immediate impact. This course of action, however, is not much more controllable than changing the demographic factors. The most controllable course is to change education-training factors. This requires only moderate lead-time and has a fairly quick impact. Two features are salient. One is the close link between education and training and job market factors that are illustrated by the symbol for information feedback. The point is,that decisions by individual students and by educational managers are influenced by their respective perceptions of employment factors.

The second feature of major concern is the "profile" of controllability. This graph suggests that governmental interventions can have their greatest leverage in the domain of education and training.

It is, perhaps, something of a truism to assert that it is not possible to consider human resource conditions without considering the training and education process. The point, however, is to come to a sense of the context within which that process takes place. What is being said, in effect, is that if there is an articulated public policy for the human resources aspect of pollution control, there is also, of necessity, a public policy for education and training in the field -- whether the latter is articulated or not. In short, education and training must be an integral part of any policy for human resources development.

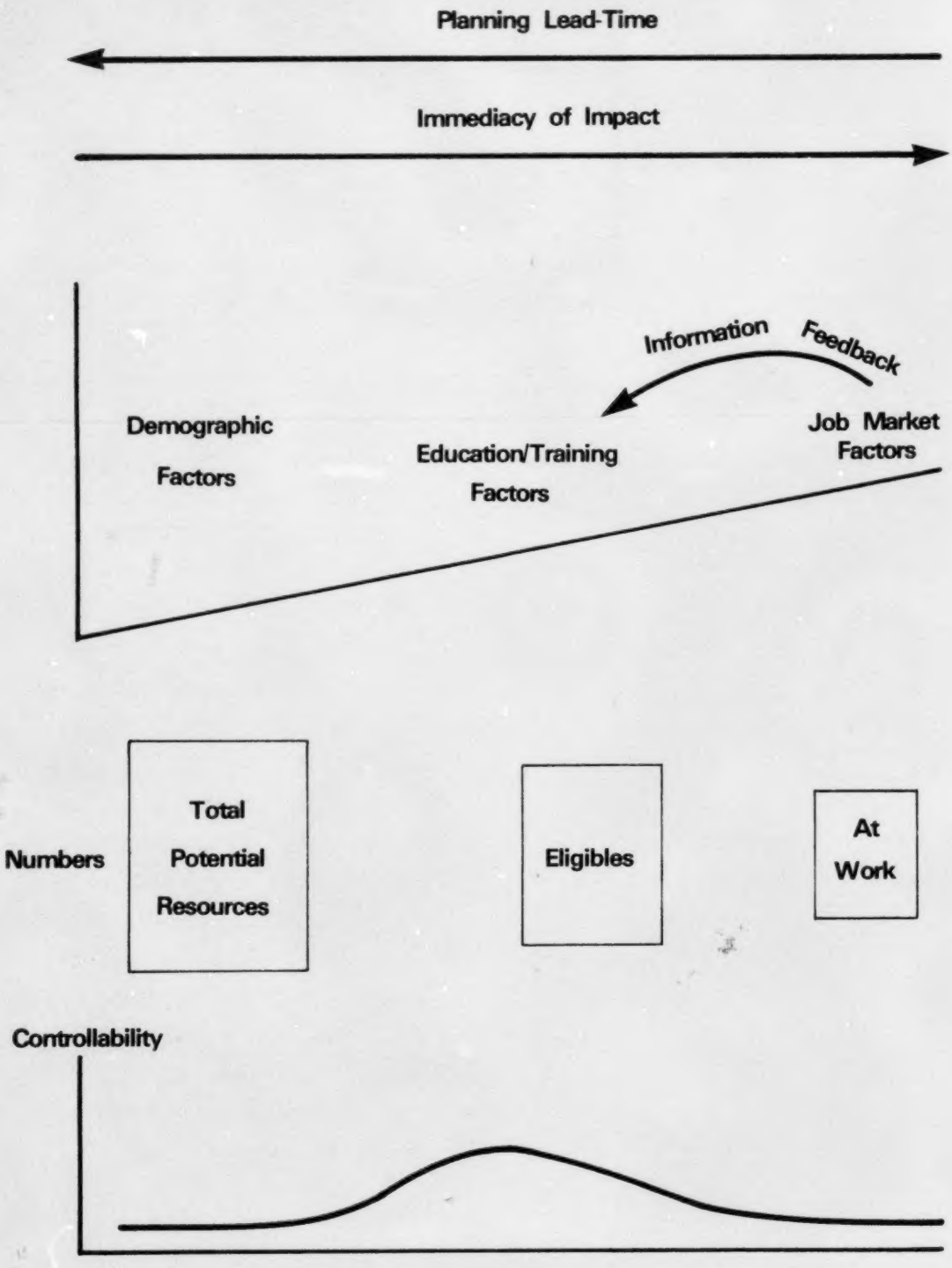


FIGURE 3.
Conceptual Aspects of the Human Resources Planning Process

The State of Knowledge Concerning
Human Resources in Water Pollution Control

The anchor point for a description of the current human resource situation is the recent report of the National Academy of Science on this topic. The conclusion drawn by the Academy panel was that while spot shortages exist and that those and kindred conditions can be projected into the future, no crisis exists now nor is one likely, given present trends. These conclusions are not entirely compatible with findings and inferences from other sources. For example, the series of surveys undertaken by Middlebrooks and his colleagues in the same general time frame as the NAS report yield a much more depressing picture.

His 1975 projection for the latter half of the decade showed a shortfall of about 15,000 graduate engineers and scientists for work in the water pollution control field. Whether we have actually experienced that level of shortfall cannot be determined precisely. As Middlebrooks predicted, much of the slack has apparently been taken-up by the employment of individuals with less than appropriate qualifications. Likewise, the recent trends toward disproportionate wage inflation for entrants into the commercial/industrial/federal side of the field is an indirect indication that Middlebrooks' projections were reasonably valid. Nothing has occurred in the half-decade since the projections were made that would mitigate the trends then plotted. If anything, the signals apparent then have become more definite even in the absence of more corroboration from survey-type studies. The only real question is whether the growing gap between demand and supply will eventuate in conditions at the action level of pollution control that will make the word crisis an appropriate description.

Most of the investigative work that has been done since the arrival of the NAS report has taken a different methodological orientation than that taken by Middlebrooks and his associates. The new tack has been in the direction of focusing on work load estimates. This approach was developed first within EPA in the mid-1970's. The idea is that more precise projections could emerge

from the aggregation of very specific, detailed data on work load in terms of person-hours for each of a myriad of jobs in a given organization. Hours per job could then be assembled according to a flexible framework of positions characteristic, for example, of a state agency. By comparing the resultant number of positions required by the work load to the number of positions already occupied, an indication of current needs would be directly determinable.

A significant advantage associated with this approach would be to minimize subjective, off-the-cuff judgements made by managers in their estimates of future personnel needs. However, the approach has two severe problems associated with it. First, the process of work load estimation itself can be very time consuming. It involves an analytic rigor and concern for detail that is not very common in situations where there are few powerful incentives for scrupulous work.

Second, if small errors do occur in the basic estimates, they tend to accumulate in the process of aggregation. There are no means to get such errors out of the computation, once they get in. In short, any distortions tend to be compounded.

Finally, it is possible that even if work load estimates show a need for a specific rate of staff augmentation, there is no real guarantee that people will actually be hired to fill the positions. It is possible to project an increase in work load and to logically infer a quantitative demand factor for people with specific capabilities; but the demand factor may only partially materialize in the actual job market.

Consequently, acceptance of the work load estimation process as a means for projecting human resources needs has been limited. However, in any case, the main revelation of the findings tends to be a substantiation of the projections made in the Middlebrooks studies.

Summary of Findings and Evaluation of Methods

The best data base on human resources for water pollution control is the aggregated work of Professor Middlebrooks. His works--those that were available at the time--provided a major resource for the National Academy of Science review. The overall import of his studies is that real, substantial shortages of human resources do exist and that the situation was deteriorating at the time of his inquiries. The sense of urgency conveyed by Middlebrooks particularly in his relatively informal pamphlet written under the aegis of the Association of Environmental Engineering Professors, was not captured in the report of the National Academy. In part, the differences between the conclusions drawn by the Academy and those drawn by the investigator, himself, can be attributed to the fact that the studies were still in progress during the time that the committee of the Academy was preparing its report. However, there also appear to have been other factors involved. Most particularly, there has emerged a generalized sense that the data were not entirely adequate to support the burden of making unequivocal projections of future supply and demand differentials. This view is shared by Middlebrooks, himself. There is, apparently, a generally shared sense that the projective picture could be drawn only in rather hazy strokes, even after the full set of studies was available.

The lesson that emerges from this sequence of events relates directly to the question of the level of investment that is appropriate for gathering data for human resource projections. One line of interpretation would be that the investment in data gathering exemplified by the Middlebrook's series was simply too small. If support had been double or triple what it was, the findings might have been sufficiently sturdy to support unequivocal forecasts. As we shall see in the following chapter, such an interpretation is questionable because projection techniques, are themselves, very limited. In other words, even a great improvement in the quality and quantity of data would not necessarily solve the problem because the forecasting models into which the data are fed are not adequate.

The alternative interpretation of the lessons available from the work of the 1970's might be that one should gear the level of investment in data collection to the limited outcomes possible with present forecasting models. Such an interpretation would support the conduct of a few modest (quick and dirty) studies more as a means of keeping in touch with broad trends rather than attempts to make rigorous analyses that would be "spuriously accurate" in the statistical sense and potentially misleading in the realm of action.

To shed more light on this alternative approach, a low-cost survey was actually conducted. A description of the study and its own implications is presented in the main body of this report.

* Prepared by The MAXIMA Corporation

Appendix B*
Alternative Means of Collecting and Interpreting Data on Human Resources for Water Pollution Control.

Introduction

The purpose of this appendix is to connect the concepts, methods and findings from the discipline of human resources analysis with the specific problem of human resources policy development in the water pollution control field. In Appendix A, we examined the actual findings from the most relevant recent studies of human resources for water pollution control. It seems fair to assert that the picture that emerges from the total ensemble of studies is not entirely clear. The available findings contain substantial ambiguity and the results are sometimes contradictory. This is not to condemn the researchers nor those who have compiled and structured the available data. It is simply to emphasize that there has been a circumstantial basis for the rather meandering course that policy directives have followed over the past decade. Also it might be the source of some modest comfort to recognize that the field of water pollution control is not alone in its difficulty. The whole fabric of human resources planning--in those vocations that utilize scientific and technical people--is somewhat tattered--as we shall see.

The objective of this appendix is to formulate some alternative strategies. It seems abundantly clear that if we simply continue to follow our established paths, we will not resolve the present ambiguities. The emphasis in presenting alternatives will be two-fold: realism in respect to what is truly feasible given available analytical tools; and efficiency in the relationship between the value of the output of data and the input of funds and time.

By way of preview, the general configuration of alternative approaches can be characterized as a monitoring system. The ideal would involve a permanent, on-going capability to sense and report fluctuations in the human resources supply and demand pattern. This standing capability would contain an "early

warning" component that could feed information directly to those having the means to influence the rate of production of human resources for water pollution control. Some of the necessary information could come from the Bureau of Labor Statistics and the U.S. Office of Education. A co-equal component would focus on current spot-problems and would disseminate reports to the entire community so that employer organizations could make optimal decisions in the expectation that the aggregate of such decisions would be commensurate with the best interests of the community and the nation at large.

Standard Human Resources Models

Background

For about fifty years, there has been a steady effort to come to grips with the overall problem of conceptualizing human resource development. In the broadest possible framework, the problem of human resources is a core problem of general economics. We cannot afford to be distracted by many of these very broad considerations but they exist as background features to our more specific concerns. For example, the overall national level of employment and unemployment is a basic parameter of economic analysis. Similarly, the composition of the workforce, workforce allocation to the various sectors of the economy at large, and movements into, out of, and within these sectors are among the chief indicators that are used to understand the condition of the economy at any given time--and to anticipate the general direction in which it is heading. The critical indices for analyzing the human resource situation are also the same as for the commercial processes in the economy: namely, supply and demand. The differential between supply and demand, regardless of whether that differential is positive or negative, is the driving force in the process of economic adjustment. At both the theoretical and practical level, the economic system--and the human resource component of that system--can be understood as a device that acts to reduce the differential between supply and demand.

During the past twenty years, a major part of the intellectual effort devoted to human resources problems has been focused on two aspects of the supply-demand model. One has been to refine the details of the dynamic factors in

the general model. Specifically, for example, investigations have been mounted to identify the minor leaks that occur in the various "pots" that contain human resources. People not only die or retire but they change their vocational goals and become marginal to a particular occupational category. As will be seen, this aspect is very germaine in the water pollution control field.

An elementary example is represented by the diagram in Figure 4. While overly simplified, this diagram does provide the sense of the factors of major concern and the beginnings of the lines of dynamic flow.

The second effort, closely related to the first, has been to improve the validity of the projections of present conditions of relative supply and demand into the future. It has turned out that the creation of a methodology for "predicting" future human resource conditions is the most vital effort in support of policy formulation and is also the most difficult and frustrating of activities. We will return to the detailed application of current methods in the water pollution control area, but for the moment it need only be asserted that the best projection contains the seeds of its own invalidation. If it is recognized as valid when made, people will act on it. By the process of acting on it, they will invalidate it. Specifically, a projected shortage in a given occupation will, if noted by the appropriate people, lead them to move into that occupational area; thus reducing, eliminating or even reversing the predicted outcome.

Another trend that should be considered is the recurrent emphasis on the development of sub-models for scholarly, scientific and technical occupations. The fuel for this particular effort has come from the government itself. It is ironic that the federal government's actions in the marketplace for highly educated human resources is the greatest source of perturbation while, at the same time, the federal government supports the studies and administrative controls that are intended to minimize occillations in actual supply and demand differentials.

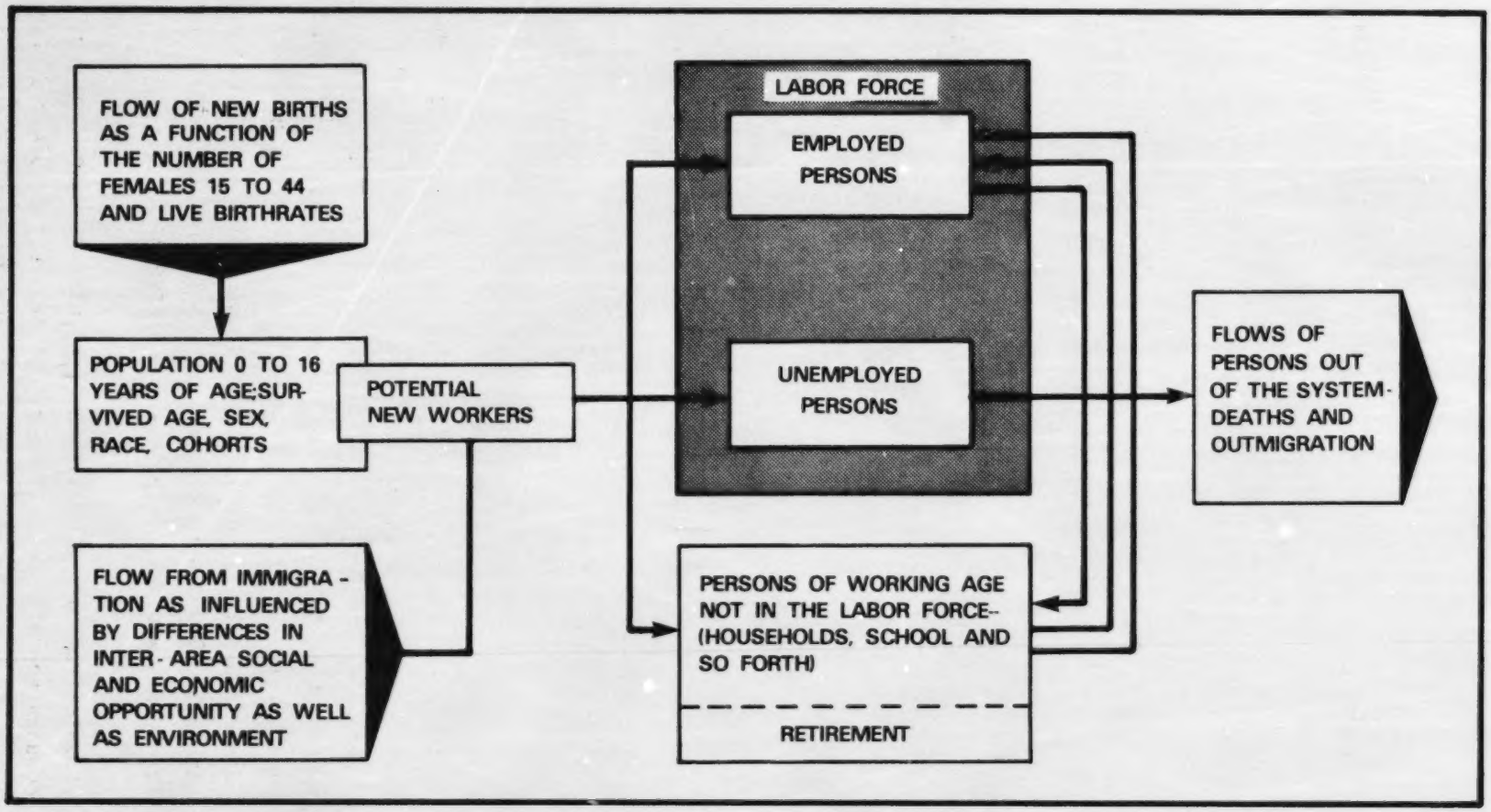

FLOW OF NEW BIRTHS AS A FUNCTION OF THE NUMBER OF FEMALES 15 TO 44 AND LIVE BIRTHRATES
POPULATION 0 TO 16 YEARS OF AGE; SURVIVED AGE, SEX, RACE, COHORTS
POTENTIAL NEW WORKERS
FLOW FROM IMMIGRATION AS INFLUENCED BY DIFFERENCES IN INTER-AREA SOCIAL AND ECONOMIC OPPORTUNITY AS WELL AS ENVIRONMENT
LABOR FORCE
EMPLOYED PERSONS
UNEMPLOYED PERSONS
PERSONS OF WORKING AGE NOT IN THE LABOR FORCE-(HOUSEHOLDS, SCHOOL AND SO FORTH)
RETIREMENT
FLOWS OF PERSONS OUT OF THE SYSTEM-DEATHS AND OUTMIGRATION

FIGURE 4. MAJOR STOCKS AND FLOWS OF PERSONS IN THE LABOR MARKET*

* MAGNUM AND SNEDEKER (1974)

Finally, before turning to the present condition of the knowledge base, it might be useful to ponder the models for a moment from the standpoint of their prospective utility. That is, what are they really for?

The answer is that the models should reveal -- quite precisely -- what interventions will work to minimize the gap between supply and demand. That is, given the model's picture of the causative linkages that exist in the marketplace, the source of any dislocation should be apparent and the point of appropriate corrective action should be clear.

The utility aspect is made even more dramatic if the consequences of failure are taken into account. For example, if a gap exists on the side of a shortage (supply is much less than demand) the outcome is wage inflation (employers chase scarce workers with money as bait) and degradation in the quality of the workforce (marginally competent workers are hired to fill the available slots). Thus the marketplace does act in a pseudo-self-correcting manner. Supply rises to meet demand over time. But if the quality of that supply is low, the stability of the surrounding economy can be adversely effected in a way that is not easy to reverse once it has occurred.

Supply and Demand Computations

Most of what is done by human resources specialists is at the macro-level of demographic analysis. An example of what is being done at the demographic level can be indicated by reference to the data and projections presented by Cartter in 1974 regarding the education flow process in the U.S. Specifically, Cartter shows that high school graduation rates have increased from about 63% in 1955-66 to over 76% in 1972-73 and were projected to rise to over 80% in the present (1980) era. As a side note, it is pertinent that the original projections made in the early 1960's were higher. It was thought then that high school graduation levels would reach 90% by the present era.

Of those who graduate from high school, over 58% enter into some type of formal post-secondary education. In the present era, using 1974 projections, we should be seeing about 59% of the appropriate age group as college entrants. About half of those who enter college, graduate. Of that set,

over 30% give graduate training a try-out. In other words, about 10% of the basic stream of the population undertake some form of graduate training. (It should be noted that the largest component of this set is in the field of education where post-graduate work is strongly sanctioned.) Finally, the rough ratio of graduate school entrants to completed doctorates is only about 15:1 or about 1 in 100 to the population at large. This number seems high because the present proportion of doctorates to the total adult population is much smaller due to the smaller production rates over the preceding forty years.

In any case, what we are looking at in the present era is a total set of about 1.5 million graduate students of whom about one-third are in professional programs. As suggested in the preceding chapter, it is in regard to this demographic set that the most controversial aspects of human resources policy are generated.

At a level of analysis that spans the macro to micro dimension, we find far more complex modes of analysis. A reasonably representative presentation of human resources modeling at this higher level of sophistication is exemplified by the work of Freeman and his colleagues. Without examining his model in its algebraic form, it is appropriate to quote as follows:

> "Standard manpower requirements analysis applies the fixed coefficient input-output model to the labor market, under the assumption that labor skill coefficients within industries are fixed and can thus be estimated by past levels. The model directs attention to the role of autonomous changes in industrial mix in altering the demand for various types of labor skills."

This type of model has several relevant applications. First, it can be used to establish coefficients of change in employment at the occupation by industry intersect over time based on historically established empirical data. Second, and again on an empirical basis, it can reveal the extent of the relative elasticities among employment level, wage structures, supply levels and demand levels. One general conclusion that has been drawn from such application of the model is that "the supply of workers to occupations is relatively elastic and stable, while the demand for labor skills is more dynamic or unstable and

less elastic with respect to wage changes." This conclusion is very much in accord with our intuitive sense of human resources market in the water pollution control "industry" over the past decade.

It should be noted, however, that the application of models of the preceding sort involve the acceptance of certain restrictive assumptions. In the present case, for example, feedback into the skill development process (i.e., training) is not a parameter. Likewise, the background factor of overall unemployment level is taken as given.

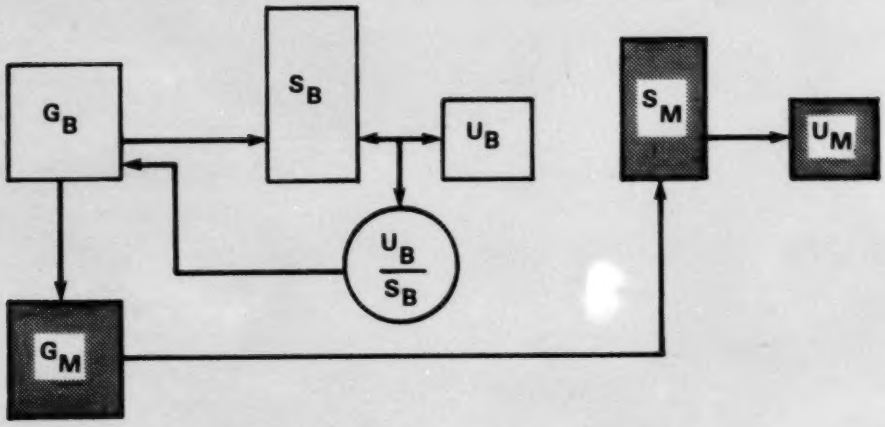
It should also be noted that within the ranks of human resource analysts there is substantial disagreement about: (a) the extent to which such general models are equally applicable across occupational specialities that vary greatly in the matter of educational requirements; and (b) the specific impact of "small" changes in wage level on supply in those specific occupations that do have high educational requirements.

Given the avowed limitations of the Freeman-type model, it is appropriate to step down a bit to a representation of a crucial process that is both simpler and more selective and which compensates, in a sense, for a specific lack in the preceding. Specifically, we can look at a one-stage, market feedback model that can be represented in both diagramatic and algebraic form as shown in Figure 5.

The main limitation on the application of this model is simply a lack of empirical data to use to establish the value of the coefficients. As the author points out: "It is frequently much easier to build theoretical models than to apply them." In fact, it is the absence of the right kinds of data and in particular of accurate data on the micro-analytic level where the whole process of modeling turns out to be weak. Consequently, we need to examine that aspect in some detail.

Figure 5.

MARKET FEEDBACK TO SUPPLY(one stage)



$$G_M = G_B \cdot K\left[\left(\frac{S_B}{U_B}\right)^n - 1\right]$$

B- BASIC

G- $\frac{\text{ENTRIES TO GRADUATE SCHOOL}}{\text{BACCALAUREATE RECIPIENTS}}$

M- MARKET

S- SUPPLY

U- UTILIZATION

Before doing so, however, we can look briefly at one additional approach to modeling. We can, perhaps, learn something from scientific manpower studies that are being done with reference to the problems of less-developed countries. The pertinence of such studies comes from the condition that relatively small numbers are involved in both the case of the less developed country and in our case, which involves a sub-specialty (water pollution control) of a sub-specialty (environmental engineering). In this regard, the conclusions of a recent paper by Moravcsik & Gibson are instructive. They emphasize the quantitative implications in terms of productive output of (a) instructional program quality and (b) what could be called critical mass in terms of the size of overall instructional program. Their model reveals that growth or even steady-state maintenance is not automatic. If programs are allowed to slip below denotable standards of quality or size the entire enterprise can die.

The Ideal Human Resources Survey

One possible approach to the consideration of better methods of diagnosing the human resources situation in water pollution control might be to indulge in more extensive, elaborate and statistically sophisticated surveys of employers. However, at base, the state-of-the-art in human resource assessment and projection is not sufficiently well developed to support such a strategy. Most of the practitioners of these arcane arts are full of misgivings and doubts. They are in no position to be otherwise because their past performance is a matter of record and the overall record is not reassuring.

The problem is not a lack of creative ability, rigor or dedication. The problem is that the data sources are inherently faulty and there is no cure (in our society) for such a condition. The fundamental weakness in the data is that employers, the source of the data, cannot be entirely accurate in their own projections. Too many exigencies exist in their operational situations.

What respondents can mainly do is to give an approximate indication of their present circumstances with respect to unfilled positions in their own organization. This datum was the focal point of the Middlebrooks's series of studies discussed in the body of this report. What they cannot do is provide a specification of the manner in which such vacancies will be filled. They can indicate their preferences but not the outcome. Levitan and his associates comment as follows: "Most employers vary their requirements to suit the state of the labor market, while the worker's mobility (or lack of mobility) renders projections of supply by occupation and industry of little value."

The Levitan group also says: "Unfortunately no reliable base exists from which to protect labor supplies by skill level or any qualitative element other than educational attainment." An even more compelling indictment is: "Most present-day manpower information systems were byproducts of programs designed for other needs."

*Prepared by the MAXIMA Corporation

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